# 2019
# Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS


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University of Idaho

Oregon State University

Washington State University

## Editors:

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*Photo by Karen Sowers*

# Welcome to our 2019 Field Days!

## 2019 Dryland Field Day Abstracts:
## Highlights of Research Progress

Washington State University
Department of Crop and Soil Sciences
Technical Report 19-1

Oregon State University
Department of Crop and Soil Science
Technical Report OSU-FDR-2019

University of Idaho
Idaho Agricultural Experiment Station
Technical Report UI-2019-1

Field Days:
OSU Pendleton Field Day—Pendleton, OR—June 11, 2019
OSU Sherman Field Day—Moro, OR—June 12, 2019
WSU Lind Field Day—Lind, WA—June 13, 2019
WSU Wilke Field Day—Davenport, WA—June 26, 2019
UI/Limagrain/CHS Primeland Crop Tour—Lewiston, ID—June 27, 2019

WOCS
WASHINGTON OILSEED CROPPING SYSTEMS
Part of the Washington State Biofuels Initiative

USDA
United States Department of Agriculture
Agricultural Research Service

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Photo by Karen Sowers

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**Photo by Doug Finkelnburg**

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# Part 1. Agronomy and Soils

## The WSU Wilke Research and Extension Farm Long-Term Rotation Summary

Aaron Esser and Derek Appel
WSU Extension

The WSU Wilke Research and Extension Farm is located on the eastern edge of Davenport, WA. Washington State University maintains and operates this facility. The farm is in a direct seed cropping system utilizing no-till fallow, winter wheat, spring cereals and broadleaf crops. Broadleaf crops are incorporated when weed pressures and market prices create opportunities for profitable production. The predominant cropping system practiced by farmers in this region is a 3-year rotation, which includes summer fallow, winter wheat, and spring cereals. Farmers are interested in intensifying rotations to reduce fallow years and increase crop diversity to improve long-term agronomic and economic stability.

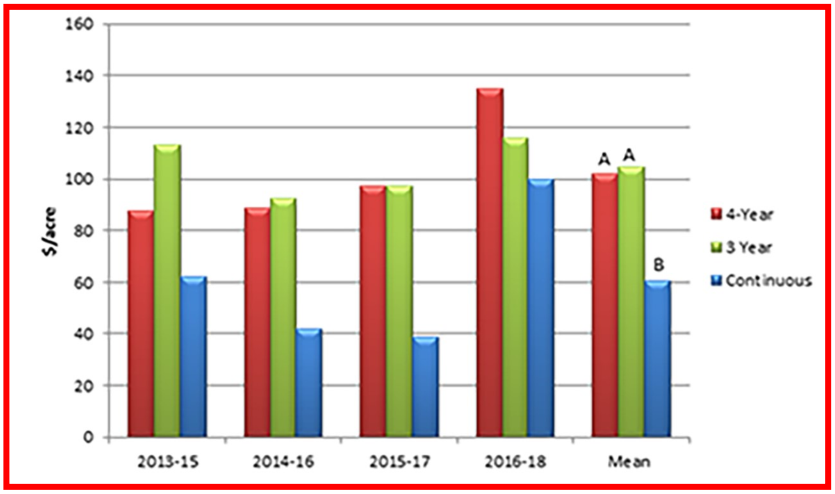

**Figure 1. Three-year average economic return over input costs of 3-year, 4-year, and continuous cropping systems at the WSU Wilke Farm. Costs do not include fixed costs associated with the farm. Means within columns assigned different case letter are significantly different ($P$<0.10).**

The south side of the farm is divided into seven plots; three plots are in a more traditional 3-year crop rotation, and four plots are in an intensified 4-year crop rotation. The north side of the farm remains in an intensified rotation that forgoes summer fallow and is in a continuous cereal grain production. Economic return over input costs (seed, fertilizer, pesticides) is analyzed in three year averages to help remove some of the year-to year variability (Fig. 1). Fixed cost associated with the farm are not included because of the variability from farm to farm across the region. Overall no significant difference in economic return over input costs has been detected between the 4-year and 3-year rotation at $102 and $104/ac. The continuous crop rotation has been significantly less at only $610/ac. More information and reports can be found at http://wilkefarm.wsu.edu/.

## Is Volunteer Wheat a Problem in Re-Crop Winter Wheat?

Stewart Wuest[1] and Judit Barroso[2]
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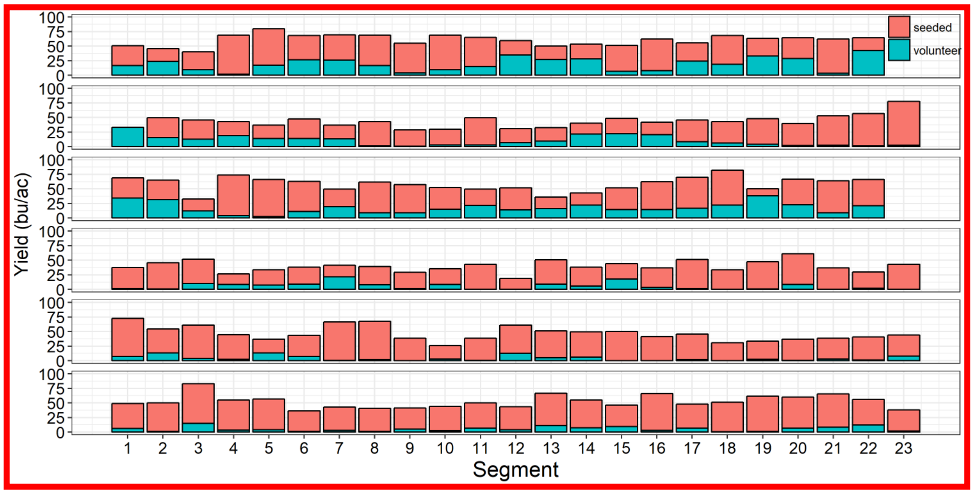
Wheat seed left in the field after harvest sprouts quickly and the resulting volunteer wheat plants are easy to control when treating for other, more problematic weeds. The exception is when a field is seeded with winter wheat annually. For some climates and soils, annual wheat production is a viable practice. When seeding winter wheat in the fall following a wheat harvest, it is likely that wheat seeds that shattered before entering the combine or were expelled with the chaff will germinate at the same time as the crop. These volunteer wheat plants will be impossible to kill using herbicides unless the currently seeded crop has a herbicide resistance trait that the previous crop does not.

If the market classes of the previous and current crop are the same, then dockage will not be a problem when marketing the grain. The important question is whether steps should be taken to minimize the presence of volunteer in the crop to maximize yield. Volunteer is most probably from shriveled grains on the surface or at shallow depth, and from seed that has not been treated for diseases. However, it is possible that the volunteer yields enough to compensate for the extra competition with the seeded crop.

We collected data in 2015 and 2016 in three fields in an intermediate-to-high rainfall zone (16 to 21 inches average annual precipitation). Average volunteer head densities were between 13% and 28% of total heads, with a high of 66% found in chaff rows. Volunteer wheat produced between 8% and 19% of total yield. To a surprising extent, areas of dense volunteer wheat stands produced similar total yield to areas with very little volunteer. On closer analyses, we determined that total yield was reduced by the presence of volunteer. At 120 volunteer wheat heads $m^{-2}$ (approximately 30 plants $m^{-2}$) the estimated yield loss averaged 10%. In addition to yield loss, there are other problems that volunteer can cause such as dockage (mentioned earlier) if the wheat varieties are different market classes, passing on herbicide resistance traits, or increasing pests or diseases in the seeded wheat. Growers should consider these issues along with the cost of a yield reduction when deciding how to minimize volunteer wheat in winter wheat fields.



**Volunteer grain yield (blue lower bar) and seeded grain yield (red upper bar) in six transects harvested in 1-foot wide and 2-foot long segments. The volunteer heads could be separated from seeded heads because one was an awnless variety and the other had awns.**

# Physical Limitations to Subsoil Health and Crop Yield in the Eastern Palouse

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Dense subsoils in the eastern Palouse may limit soil health by impeding root exploration and crop growth. The primary objective of this research was to quantify the effect of dense subsoils on winter wheat rooting depth, soil water use, and crop productivity. This research was conducted in two commercial winter wheat sites in eastern Washington and northern Idaho. A total of forty soil profiles were sampled for soil bulk density, root density, and post-harvest soil water content. Dense subsoils negatively affected winter wheat root density and more severely affected root density in shallow soil layers. Seventy percent of sampled profiles had root systems limited to soil depths of 48 inches or shallower. Shallow rooting depth was associated with lower soil water depletion from the subsoil and lower grain yield. Crop roots in restricted profiles may not have had access to subsoil water resulting in subsequent yield loss. These results suggest that producers can take two main approaches to addressing the negative production effects of dense subsoils on their farms: i) keep existing topsoil in place, and ii) improve subsoil health over time. Keeping the soil surface covered through the winter can slow erosion while long-term use of deep-rooted rotational crops with taproots, like rapeseed, may help develop pores through dense subsoils.

# Advancing Crop Stress Monitoring and Sampling Using Unmanned Aerial System

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The Unmanned Aerial System (UAS, also known as a drone) is widely used for many civil operations, including emergency response, hazard monitoring, delivery service, and public safety, but the agricultural UAS market, in particular is stunning due to recent technology advancements on smartphone and sensing devices. Most UAS applications in agriculture, however, mainly focus on weed detection and drought monitoring using simple sensors, such as the Normalized Difference Vegetation Index (NDVI). Little research so far exists on UAS-driven insect sampling in the field of agricultural engineering and extension literacy. Therefore, the goal of this research is to advance crop stress monitoring (possibly induced by water shortage, nutrient stress, and insect outbreak) and sampling activities (e.g., lygus bug) using UAS technology equipped with a hyperspectral sensor (Fig. 1). The preliminary result indicates that UAS-based insect scouting method perform very well in the sense that it can show a good correlation with a traditional scouting method by hand with 15-inch diameter sweep net. In addition to UAS-based research activities, the team has also developed a drone education program titled “Idaho Drone League (iDrone)” funded by University of Idaho (UI) to promote STEM pipelines and UAS workforce for future growers. During iDrone, Idaho youth (7th – 11th grade students) have learned basic concepts in automatic control, robotics, and UAS technologies along with hands-on project opportunities indoor and outdoor (Fig. 2). We will feature these UAS research and education programs led by UI faculty at the meeting.

**Figure 1. The field set up to collect lygus bug samples using Unmanned Aerial Systems (UAS) near Caldwell, Idaho. Summer 2018.**

**Figure 2. Idaho Drone League (iDrone) 4-H during the State 4-H Teen Association Convention (STAC 2018) at the Kibbie Dome, University of Idaho, Moscow.**

# Chemical Fallow Stores More Soil Water and Produces More Wheat Yield than Trash Fallow

STEPHEN MACHADO AND LARRY PRITCHETT
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Yes, winter wheat yield following chemical fallow (WW-CF) was higher than winter wheat yield following “Trashy Fallow” (WW-TF) that is practiced in low precipitation (<11 in.) regions of northcentral Oregon. We came to this

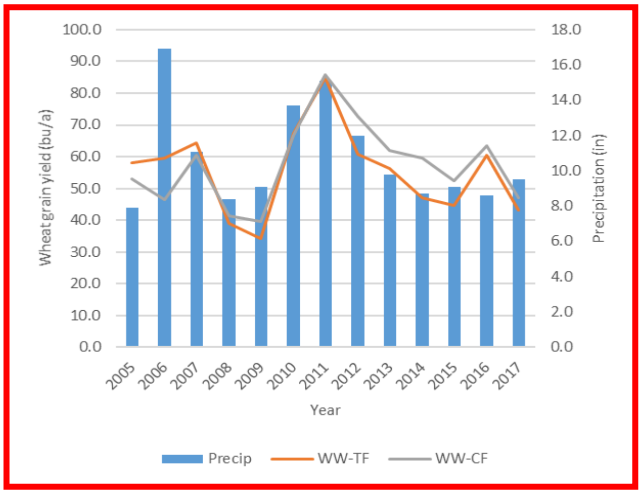

**Figure 1. Winter wheat grain yields following “Trashy” and Chemical Fallow, 2004-17 Crop-years, CBARC, Moro, Oregon.**

conclusion after 15 years of study (Fig. 1). Wheat yield was higher under WW-TF than WW-CF during the first 4 crop years but, thereafter, yield was higher under WW-CF than WW-TF. Fallowing once in three years as in the Winter wheat-spring barely-chemical fallow (WW-SB-CF) system improved yields over the WW-CF system. The 15-year average yields under WW-TF, WW-CF, and WW-SB-SF were 55.4, 57.7, and 59 bu/a, respectively. The differences in yield among the systems was not due to SOC as the three fallow systems didn’t not differ significantly in SOC (~16 tons/a in the top foot). High yields under chem fallow treatments were attributed to increased water infiltration and storage throughout the 40-in soil depth profile (Fig. 2-showing only to the 12 in. depth moisture content).

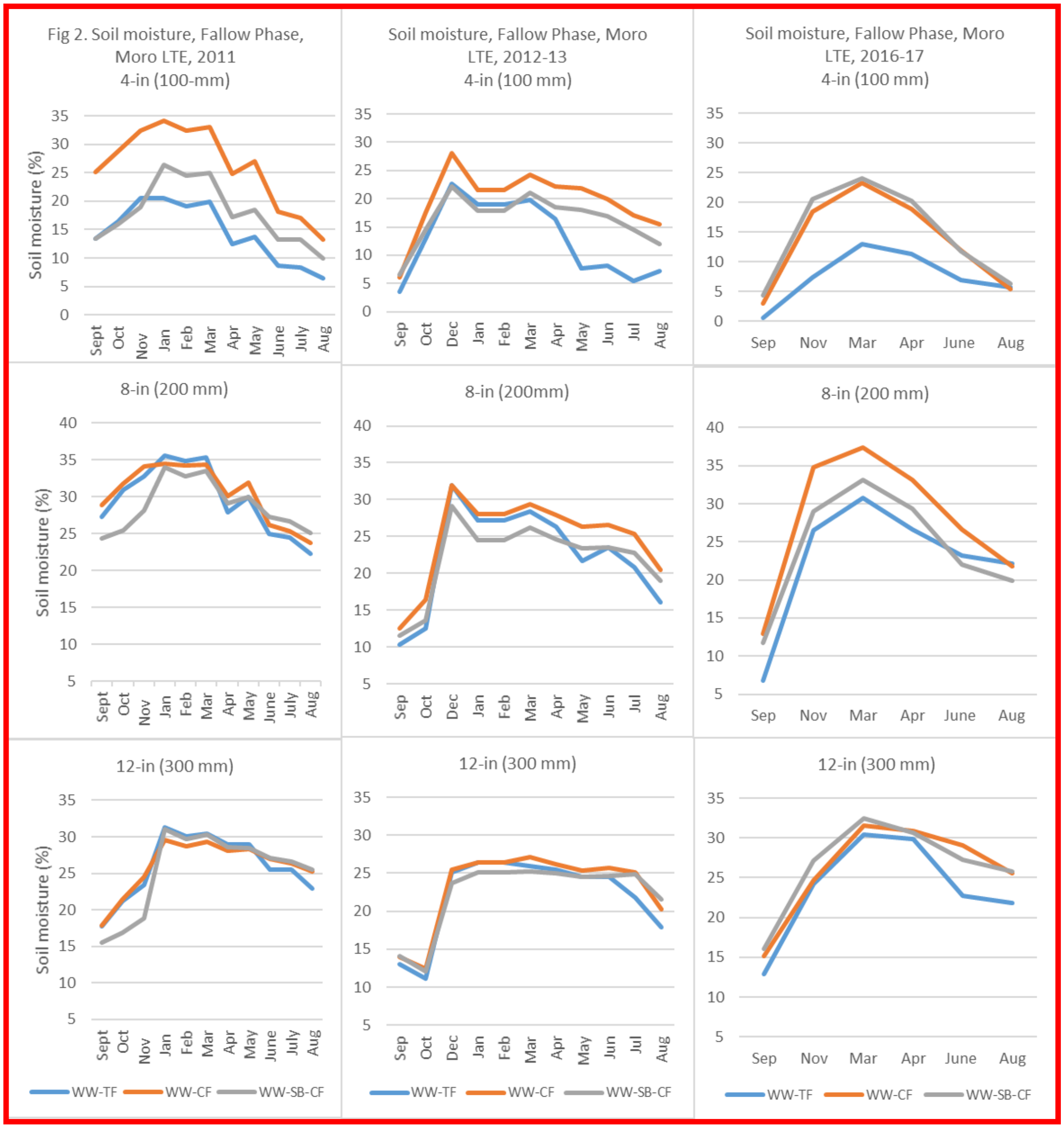

**Figure 2. Soil moisture, fallow phase, showing only to the 12 inch depth moisture content.**

# Soil Carbon Loss by Wind Erosion of Summer Fallow Fields in Washington's Dryland Wheat Region

BRENTON SHARRATT[1], ANN KENNEDY[1], JEREMY HANSEN[1], AND BILL SCHILLINGER[2]
[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU LIND

**Overview:** Wind erosion of cropland negatively affects soil quality and productivity in the winter wheat–summer fallow (WW-SF) region of the inland Pacific Northwest. Loss of soil diminishes the finite resource base and concurrent loss of soil organic carbon (C) affects the inherent physical, chemical, and biological properties of the soil. This study aimed to quantify soil organic C loss from windblown summer fallow soils. Creep and Big Spring Number Eight samplers (Fig. 1) were used to trap sediment above an eroding soil during 13 wind erosion events over an 8-year period in Adams County, WA. Recording instruments were installed on both the windward and leeward sides of 160-acre fields. Averaged across all sites and wind events, soil C loss from fields ranged from 0.26 to 17 pounds of C per acre. The ongoing decline in soil organic C since the advent of dryland farming in the region 140 years ago is most commonly attributed to degradation by microbes and oxidation. However, our data, combined with historic accounts of massive dust storms in the WW-SF region, strongly indicate that most loss of soil organic C was caused by wind erosion. Practice conservation-till and no-till to reduce wind erosion on your farm in the WW-SF region.

**Figure 1. An array of dust emission recording instruments were installed on both the leeward and windward sides of 160-acre summer fallow fields in Adams County over eight years to quantify soil and carbon loss during wind storms.**

**Conclusion:** Historical accounts of wind erosion in the region suggest that up to 84 tons of soil per acre can erode during single 24-hour dust storms in Adams County. It is estimated that about 1200 pounds of soil organic C per acre would be lost in such a major dust storm. That's a huge loss of carbon! While this hypothetical loss is substantially higher than the losses measured in our study, it is lower than measured from some studies around the world. Carbon is the single most important component affecting the physical, chemical, and biological properties of soils. We must keep our soils from blowing. A detailed report on our study in Adams County was published in the Soil Science Society of America Journal in 2018.

# Maximizing Gains While Minimizing Losses with Your Choice of Rotational Crops in 2019

KATHLEEN PAINTER, KEN HART, AND DOUG FINKELNBURG
UI EXTENSION

Current market conditions are indicating a lack of demand for pulse crops, particularly garbanzos, with current prices at about half of last year's price (Table 1). While there are many proven benefits of rotating grain crops with non-grain crops, losing money from a nonprofitable crop choice is not an attractive option. Given current market conditions, growers in the dryland annual cropping region may find that growing an inexpensive cover crop would potentially help reduce weed and disease pressure while fixing nitrogen, building organic matter, provide grazing or reducing erosion, particularly if they have a specific problem area they need to address.

Without assigning any economic value to potential soil health, nitrogen fixing, yield enhancing, or grazing benefits, a cover crop will be a somewhat costly investment, averaging from $88 to $103 per acre, based on costs for four different mixes created for this region: a fall-seeded nitrogen fixing blend, a grazing blend, a soil building blend, and a value blend (Rainier Seed). The costs of planting the least expensive crop mix is compared to returns over total costs from rotational crops in a direct seed rotation in Figure 1. A detailed spreadsheet with cost and returns for each crop as well as several cover crop recommendations is available at https://www.uidaho.edu/cals/idaho-agbiz/crop-budgets or by request (kpainter@uidaho.edu).

**Table 1. Crop yield and 2019 farmgate price estimates by crop.**

| By Crop | Unit | Yield per Acre | 2019 Farmgate Price Estimate per Unit |
|---|---|---|---|
| WW | bu | 90 | $5.50 |
| SWSW | bu | 65 | $5.50 |
| DNS | bu | 60 | $6.00 |
| SB | ton | 1.8 | $125 |
| P | lb | 2000 | $0.11 |
| L | lb | 1200 | $0.11 |
| SC | lb | 1800 | $0.16 |
| Garbs | lb | 1400 | $0.18 |

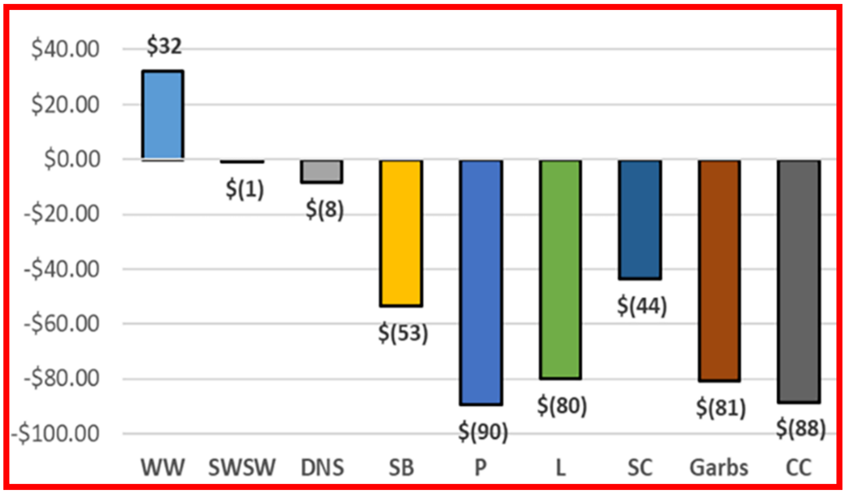

**Figure 1. Estimated net returns over total costs by crop, 2019 farmgate crop price estimates ($/acre).**

# Spring Cereal and Cereal-Pea Forage Productivity and Nutrition

DOUG FINKELNBURG, JIM CHURCH, AND KEN HART
UI EXTENSION

Cattle producers in northern Idaho need high quality forage for optimal animal health and growth. Farmers in the region face challenging returns on spring grain or grain-legume crops. In other areas of the country where these conditions exist, ground cropped with annual-grains is frequently converted to single-season forage production. This work explores

**Figure 1. Proleaf 234 Oat/Flex Pea plot.**

the performance of spring cereal and cereal-pea forages in two location on the Camas Prairie in North-Central Idaho conducted at the request of area cattle-producers.

Forage oats, barley, triticale and millet as well as cereal-forage pea mixes were trialed in Idaho and Lewis Counties in 2018. A randomized complete block design with four replications of small plots was used. Quality samples were analyzed at Northwest Labs in Jerome, ID.

Growing conditions were wetter than average and planting was delayed until May 15th. Fertility was added based on soil tests to provide around 80 lbs/acre-N overall. Swathing was targeted during flowering stage intending to capture the maximum tonnage before quality decline. Triticale, oats, and barley were harvested July 16th. Millets were cut July 24th. Weeds were controlled with 2, 4-D amine and hand weeding in the cereal-pea plots. Wildlife grazing at the Idaho Co. plots increased variability in results.

On average the highest yields were obtained with Haybet Barley as well as the lowest protein observed. NZA 4.14-Oat, Tricale 141-Triticale/Flex Pea mix, Tricale 141-Triticale, Proleaf 234-Oat/Flex Peas, and Otanas Oat had the highest proteins overall. NZA 4.14-Oat, Everleaf 114-Oat and Proso Millet contained the most total digestible nutrients. These trials will be conducted again in 2019 and provide needed information about the comparative performance and value of currently available forage cereals and cereal-pea mixes.

**Table 1. Yield and quality results. All plots direct-seeded with 100 lbs of 16-20-0-14.**

| | Lewis County | Idaho County | Combined Yield | Crude Protein | Acid Detergent Fiber | aNDF (Neutral Detergent Fiber) | Net Energy for Lactation | Total Digestible Nutrients Est. |
|---|---|---|---|---|---|---|---|---|
| Variety | ——dry weight tons/acre—— | | | % | % | % | Mcal/lb | % |
| Tricale 141 Triticale | 2.76 | 1.33 | 2.04 | **10.8** | 34.5 | **57.9** | **0.59** | 52.3 |
| Otanas Oat | **3.35** | 1.37 | 2.36 | **10.5** | 36.1 | **58.7** | 0.55 | 53.8 |
| Proleaf 234 Oat | 2.99 | **1.59** | 2.29 | 9.9 | 36.5 | **59.9** | 0.54 | 53.2 |
| Everleaf 114 Oat | 2.55 | **1.61** | 2.08 | **10.5** | 34.4 | 55.1 | 0.57 | **56.3** |
| NZA 4.14 Oat | 2.68 | **1.54** | 2.11 | **11.4** | 33.3 | 54.3 | **0.59** | **57.8** |
| Haybet Barley | **3.83** | **1.80** | **2.81** | 7.9 | 33.4 | 54.6 | **0.61** | 50.4 |
| Stockford Barley | 2.94 | 1.37 | 2.16 | 9.4 | 33.1 | 53.7 | **0.61** | 51.6 |
| Proso Millit | 1.92 | **1.45** | 1.71 | 9.1 | 34.0 | 51.8 | 0.58 | **56.8** |
| German Millit | 1.67 | 1.03 | 1.39 | 10.2 | 36.3 | 55.9 | 0.54 | 53.5 |
| Tricale141 Triticale/Flex Peas | 2.61 | 0.95 | 1.78 | **10.9** | 38.3 | **59.0** | 0.58 | 51.2 |
| Proleaf 234 Oats/Flex Peas | 2.52 | 1.32 | 1.92 | **10.8** | 35.6 | 58.2 | 0.60 | 52.8 |
| Stockford Barley/Flex Peas | 3.06 | 1.36 | 2.21 | 9.5 | **37.1** | 53.5 | **0.59** | 50.6 |
| *Average* | *2.75* | *1.42* | *2.09* | *10.0* | *35.2* | *56.1* | *0.58* | *53.5* |
| LSD (0.05) | 0.58 | 0.38 | 0.34 | 1.2 | 1.7 | 3.4 | 0.02 | 2.0 |
| CV (%) | 15 | 18 | 16.26 | 11.8 | 4.9 | 6.0 | 4.22 | 3.7 |

*bold values are statistically similar to the highest value in their column.

# The Value of Calcium Carbonate Application in Low pH Soil Conditions

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[1]WSU EXTENSION; [2]FARMER COOPERATOR

Farmers across the wheat producing region of eastern Washington are seeing declining soil pH caused by ammonium-based fertilizer application. Farmers who have adopted conservation tillage may also observe a stratification of strongly acidic soils within the band of fertilizer application. When soil pH is low, microbes, fertility and soil chemistry shift creating an environment adverse to soil and crop health. Liming materials, such as calcium carbonate (CC), are applied to increase soil pH, however this is not a common practice across the region. In the spring of 2015, a 3-year project was started to examine the benefits of CC applications in a strongly acid soil (pH as low as 4.9). An on-farm trials was established examining three treatments; 1. a no CC check, 2. CC at 31 gal/ac and, 3. CC at 59 gal/ac. Each gallon provides 12 pounds of CC. The treatments were applied on April 17, 2015 and incorporated. The trial was then seeded to spring wheat with a Horsh direct seed drill. Chickpeas were seeded in the spring of 2016 and winter wheat was seeded in the fall of 2016. Soil pH changes was within the top 3 inches of the soil profile where pH increased from 5.09 to 5.37 after one year. Averaged over all three years, no difference in yield was detected, and return over investment was greatest with the check with $380/ac compared to $354/ac with 32 gal/ac and only $317/ac with 31/ac. Overall, more pounds of lime are needed to change soil conditions and improve yield potential over time.

# Carbon Sequestration Potential in Cropland Soils in the Inland Pacific Northwest: A Summary of Existing Knowledge and Gaps

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Cropland agricultural soils have the potential to either release (be a source of) or capture and sequester (become a sink for) carbon. A white paper recently published on the website for the Center for Sustaining Agriculture and Natural Resources provides a summary of existing experimental and modeling evidence for the potential that cropland soils in the inland Pacific Northwest - including dryland soils - have for sequestering organic carbon, and identifies remaining knowledge gaps. The purpose of this summary is to provide context for ongoing regional policy discussions related to fostering farming practices that show the best potential for carbon sequestration, and to ensure these discussions are grounded in an understanding of the dynamics of PNW agricultural systems and agricultural carbon. Regional research on the impacts of agricultural management strategies on carbon sequestration are reviewed, including tillage, crop rotation, fallowing, perennial crops, crop fertilization, soil amendments, reduced burning, and reduced erosion. We present a few key messages here, with supporting literature and the full white paper available at the link below.

Reducing tillage can increase soil organic carbon, particularly in the higher rainfall, annual cropping agro-ecological class. Conversion from conventional tillage to no-till has greater impact than reduced tillage, and carbon gains occur mainly in the first decade after the change is implemented. Modifying crop rotations to include crops that produce greater residue has potential to increase SOC, but the magnitude of effects depend on other factors (e.g., tillage, rainfall). Cropping intensification and fallow reduction, where feasible, can increase SOC, potentially as much as conversion to no-till. Addition of organic soil amendments can maintain, or potentially increase SOC with amendments that have undergone microbial processing (e.g., biosolids, manure) having the greatest C sequestration efficiency.

Our summary of studies in dryland cropping systems suggests that a number of practices can provide real but modest contributions to carbon sequestration, with the likelihood of substantial co-benefits including soil conservation, improved ability to store water in soils, increased microbial activity, and sustaining long-term crop productivity. The opportunities to build soil organic carbon are greater in annually cropped systems with higher productivity, though the benefits of particular management practices are variable and depend on multiple environmental and physical conditions. There is an ongoing need to establish credible estimates of carbon fluxes for Pacific Northwest agricultural systems accompanied by monitoring to determine whether cropland soils are achieving carbon sequestration goals. Thoughtful consideration of the environmental and production contexts surrounding Pacific Northwest agriculture, combined with targeted research to identify the most effective carbon sequestration practices, could lead to the development of policies that can realize the real contributions that croplands in the Pacific Northwest can make to climate change mitigation efforts.

For more information, see the full white paper: http://tinyurl.com/y37s62ap.

# Part 2. Oilseeds and Other Alternative Crops

## Nitrogen Source and Rate to Minimize Damage Caused by Free Ammonia in Canola

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When planning Nitrogen (N) fertilizer application the source of the fertilizer should be considered in order to optimize nutrient availability as well as to avoid damaging seedling root systems. Canola root systems have been shown to be sensitive to urea banded below the seeds. The two primary considerations when choosing a safe source of N fertilizer are the salt toxicity and ammonia/ammonium toxicity. The conversion of ammonium to free ammonia is primarily controlled by the initial pH of the fertilizer reaction. A high pH will lead to more free ammonia than ammonium. Free ammonia has been shown to be extremely toxic to plant cells. Therefore fertilizers with a high pH would be expected to release more free ammonia and consequently have a higher level of toxicity. Urea, Anhydrous Ammonia, and Aqua Ammonia all have pH greater than 8 in solution. Fertilizers with a pH lower than 8 are Ammonium Sulfate, Mono-Ammonium Phosphate, and Di-Ammonium Phosphate. In this study we compared the application of ammonium sulfate (AS) (pH = 5-6, partial salt index = 3.52), urea (pH = 8.5-9.5, partial salt index = 1.61), and urea ammonium nitrate (UAN) (pH = 7, partial salt index = 2.22). In order to establish safe planting guidelines a root assay was conducted in a Palouse Silt Loam soil with N fertilizer sources banded 2" below the seed row at increasing rates. The gradients of the rates were used to model tap root survival and estimate the LD50s for tap root survival. The LD50 is the rate at which would expect 50% of the tap roots to die. The unconventional unit of mg/cm was used to make the applications and dose response because the actual amount of N which the root is exposed to depends heavily on the row spacing and the application rate (lbs N/A). In Table 1, you can see a conversion between the LD50 (mg/cm) and field rates (lbs N/A) at different row spacings for all three sources. From this table you can see that UAN is a much safer source of N to apply than UAN and that closer row spacing will also decrease the potential for root death.

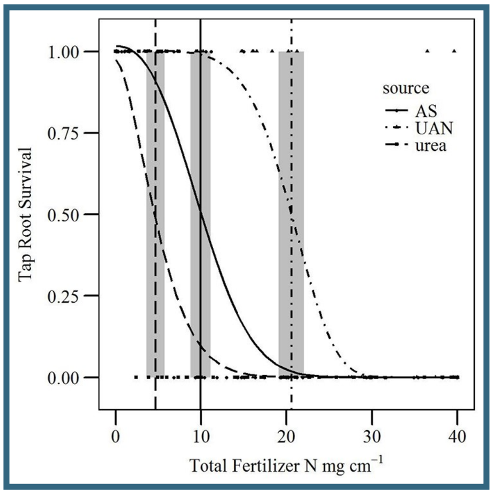

**Figure 1. Modeled dose response and estimated LD50s for Ammonium Sulfate (AS), Urea Ammonium Nitrate (UAN), and Urea. LD50s can be converted to lbs N/A for each source by using Table 1.**

**Take away points:** It was determined that canola roots are more sensitive to urea than ammonium sulfate or UAN. This is likely because urea would produce higher levels of free ammonia following dissolution.

**Table 1. LD50s of canola tap root survival exposed urea, AS, and UAN**

| | | Row Spacing (in) | | |
|---|---|---|---|---|
| Source | LD50 (mg N/cm) | 6 | 12 | 18 |
| | | Rate (lbs N/A) | | |
| urea | 4.7 | 27 | 14 | 9 |
| AS | 9.7 | 57 | 28 | 19 |
| UAN | 20.6 | 120 | 60 | 40 |

# Spring Canola and Chickpea Value in a Cereal Grain Rotation

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Canola (*Brassica napus* L.) in rotation with wheat (*Triticum aestivum*) has been an option for farmers in the dryland cropping region of the Pacific Norwest for over 25 years, yet adoption has been limited because of market access, profitability and overall unfamiliarity with the crop. In 2014 a large-scale multi-year rotation study was initiated comparing spring wheat, canola and chickpea (*Cicer arietinum* L.) (1st year) in rotation with winter wheat (WW) (2nd year) and spring wheat (3rd year). The experimental design is a randomized complete block with four replications and plot size 8 x 61 meters. Each crop rotation is examined over two cycles (i.e. 6 years) and was repeated in 2015 and 2016. The study is located at the WSU Wilke Research and Extension Farm which receives an average of 350 mm of precipitation. Data collected included seed yield, costs of production, economic returns, and subsequent crop production yields and quality. Gross economic returns are calculated using local F.O.B. prices on September 15 each year, and canola and chickpea yearly contract prices. Cost of production is the input costs (seed, fertilizer, herbicides, etc.) only. Spring wheat had the greatest yield averaging 2,311 kg ha$^{-1}$, and there is no significant difference in yield between canola and chickpea at 1,035 and 1,003 kg ha$^{-1}$, respectively. Over the first three years, subsequent WW yields were greatest following chickpea at 3,978 kg ha$^{-1}$, second following canola at 3,734 kg ha$^{-1}$, and lowest following wheat at only 3,399 kg ha$^{-1}$. Over the two-year cropping sequence economic return over costs with chickpea/WW has averaged \$254 ha$^{-1}$, wheat/WW at has averaged \$208 ha$^{-1}$ and canola/WW has averaged \$164 ha$^{-1}$. Overall, canola and chickpea both show positive rotation effects on following WW yield. Grower profit will vary according to grain prices which will fluctuate over years.

# Improving Seed Size and Seedling Emergence in Transgenic *Camelina sativa* by Overexpressing the *Atsob3-6* Gene Variant

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Seed shape and size are important agronomic traits because they can affect yield, ease of harvesting, and seedling establishment, especially under adverse conditions (e.g. drought, weed and pest pressure). The development of crop varieties that have large seeds and long hypocotyls as seedlings, yet maintain normal growth characteristics as adults, is challenging for traditional breeding because the regulation of seed/seedling size is complex and can be linked to other agronomic traits such as heading date or flowering time.

Based on our previous findings, some of the *AHL (AT-Hook Containing, Nuclear Localized)* genes play crucial roles in determining seed size and hypocotyl length in *Arabidopsis thaliana*, a model brassica plant. When we express particular mutant form, *Atsob3-6,* of the *AHL* gene *AtAHL29/SOB3* (*Suppressor of Phytochrome B-4 #3*) the resulting transgenic *Arabidopsis thaliana* plants have normal adult growth that give rise to larger seeds and seedlings with longer hypocotyls than the wild type. *Arabidopsis thaliana* and *Camelina sativa* are from same family (Brassicas) and both have similar genomes. *Camelina sativa* is an emerging oilseed crop in dryland cropping systems.

Based on our preliminary results, we proposed: (1) to compare seed size of different mutations of *AtAHL29/SOB3* to identify the specific mutations that confer bigger seeds and longer hypocotyls than the wild type and; (2) translate the finding from *Arabidopsis thaliana* to the oil seed crop *Camelina sativa*.

In this study we have generated transgenic lines of *Arabidopsis thaliana* overexpressing *Atsob3-6*. We have then generated transgenic *Camelina sativa* plants overexpressing *Atsob3-6* as well as a similar gene variant from *Camelina sativa* (*Cssob3-6*). Seedling hypocotyl length, seed size, seed weight and seedling emergence from deep-planting assays were then measured. Our results show that transgenic plants expressing *Atsob3-6* confer bigger seeds and taller seedlings than non-transgenic lines in *Arabidopsis thaliana*. These *Atsob3-6* transgenic lines make seeds that are 50% bigger and seedlings that are twice as tall as non-transgenic plants. When we overexpress *Atsob3-6* in *Camelina sativa*, we increase seedling height (Fig. 1a), seed area (Fig. 1b) and seed weight (Fig. 1c) compared to non-transgenic plants. When we overexpress the *Camelina sativa* variant, *Cssob3-6*, in *Camelina sativa*, seeds are ~30% bigger and seedlings ~50% taller than non-transgenic plants. In order to evaluate if the larger *Atsob3-6* seeds improve *Camelina sativa* emergence from sub-surface planting, we planted two independent transgenic lines (*Atsob3-6-OX-1*, *Atsob3-6-OX-2*) and wild-type seeds 6 cm deep in moist, compacted sunshine mix #1. Approximately 25% of the *Atsob3-6-OX* transgenic seedlings emerged compared to 2% of the wild type (Fig. 2a). Hypocotyl measurements of all germinated seedlings demonstrated that *Atsob3-6-OX* increased seedling height in sub-surface planting (Fig. 2b). We also tested *Camelina sativa* emergence from sub-surface planting in dry Palouse silt loam with 30% of the *Atsob3-6-OX* transgenic seedlings and 0% of wild-type seedlings emerging (Fig. 2c). All genotypes in our emergence assays had 100% germination.

Taken together, over-expression of *Atsob3-6* increases seed size, hypocotyl length and stand establishment *Camelina sativa*.

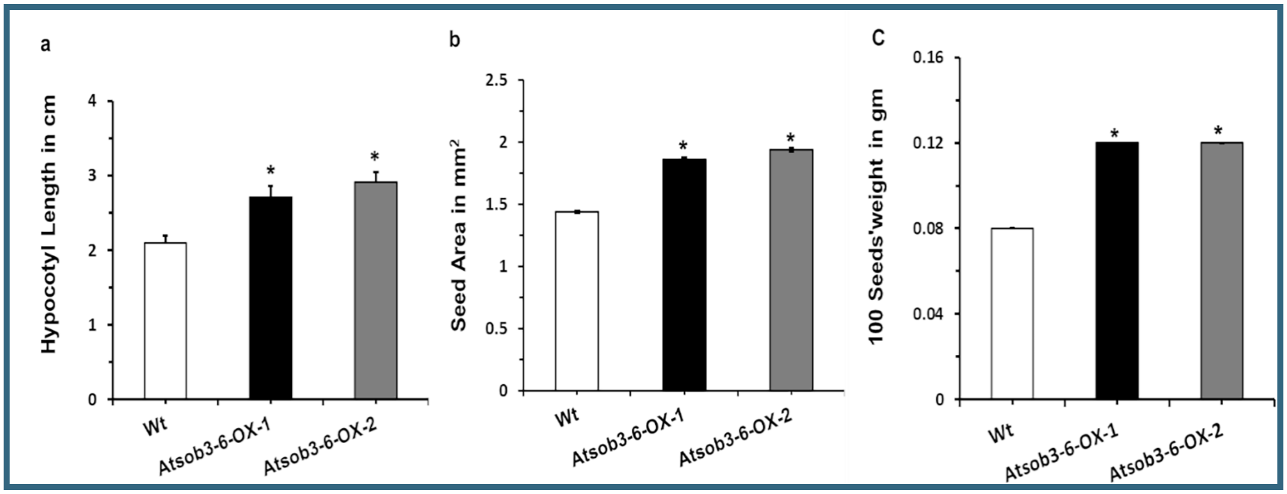

**Figure 1. The *Atsob3-6* allele regulates hypocotyl length, seed size and seed weight when overexpressed in *Camelina sativa*. Two independent *Atsob3-6-OX* transgenic camelina lines increased hypocotyl length (a) seed size (b) and seed weight (c) when compared to the wild type (Wt). *n* = 60 for hypocotyl length. *n* = 100 for seed area. *n* = 300 for seed weight, * p < 0.0001**

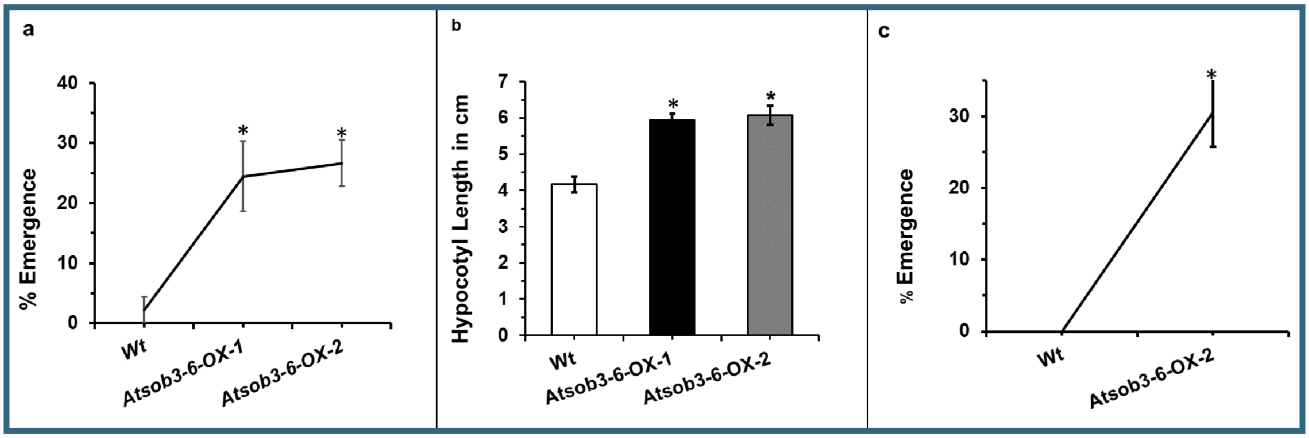

**Figure 2. *Atsob3-6-OX* confers better seedlings emergence when expressed in *Camelina sativa*. Seeds of two independent *Atsob3-6-OX* lines and the wild type (Wt) were germinated beneath 6 cm of lightly compacted potting mix at 25°C for seven days before measuring percent emergence (a), and total hypocotyl length within and above the soil (b), *n* = 45. Seedling emergence of *Atsob3-6-OX-2* and wild-type seedlings was also measured seven days after planting beneath 6 cm of dry Palouse silt loam (c), *n* = 36, *p< 0.0001.**

# Environmental Effects on Nectar and Pollinators in Canola

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Flowers produce nectar as an attractant for pollinators. Typically, bees are attracted to flowers with higher nectar volume, or higher sugar concentration. Nectar provides the primary source of energy in the form of carbohydrates to adult bees, and for honey and bumble bees, is also the primary ingredient in honey. Canola doesn't require insect pollination but can see a nearly 40% increase in yield when insect pollinators are present. Seasonal climate shifts and drought conditions may reduce overall water availability to plants. Nectar is made mostly of water, so we were curious if reduced water availability would change the quantity or quality of nectar. We expected that plants in a drought scenario would produce a lower volume of nectar, and that the sugar concentration of the nectar available would be higher. We were also interested in bee communities at farms dependent on nectar traits. We conducted a greenhouse experiment where canola plants were grown with either full availability to water, or half availability to water. We then measured the amount and sugar concentration of nectar produced. We found that when plants had full access to water, plants produced significantly more flowers and the volume of nectar produced was significantly higher than the volume produced by plants with less water access. We found no significant differences in the sugar concentration, but we found that some plants did not produce a measurable volume of nectar when they were part of the reduced water scheme. We tested this in three different canola varieties and found that NCC 101S (variety B) produced more nectar overall than HyClass930 or Invigor L233P. In a field observation, we found variable communities of bees at canola fields producing differing quantities of nectar suggesting that nectar traits are not the sole attractor for pollinators.

Var A: HyClass 930

Var B: NCC 101S

Var C: Invigor L233P

In the 2019 field season, we plan to resample the pollinator communities, and we will also assess how landscape traits might affect pollinator populations using GIS methods.

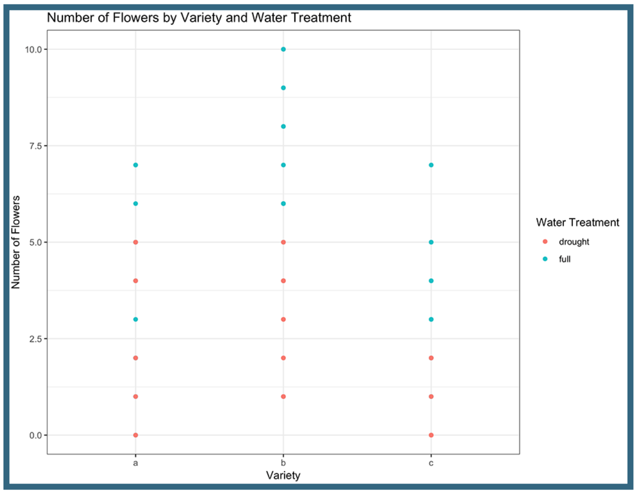

**Figure 1. Number of flowers by variety and water treatment.**

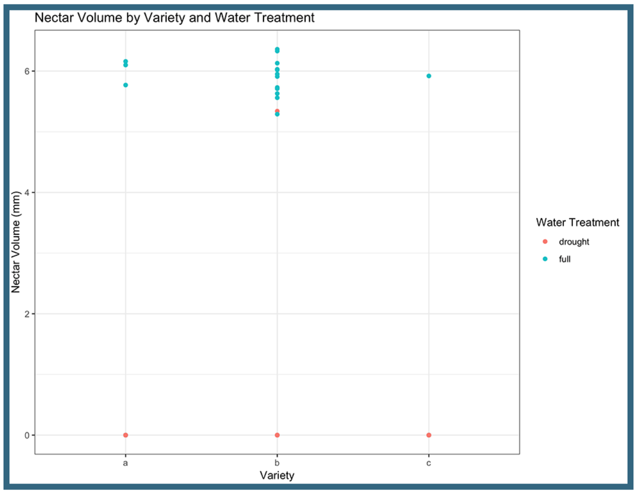

**Figure 2. Nectar volume by variety and water treatment.**

# Canola in Wheat-Based Rotations: Update from Two Long-Term Field Experiments Near Ritzville

BILL SCHILLINGER[1], JOHN JACOBSEN[1], RON JIRAVA[2], TIM PAULITZ[3], JEREMY HANSEN[3], DAN SCHLATTER[3], CASSANDRA RIESER[2], AND DAVE HUGGINS[3]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]FARMER COLLABORATOR, RITZVILLE; [3]USDA-ARS

Two long-term canola cropping systems experiments are well underway at the Ron Jirava farm near Ritzville, WA. In Study 1, canola grown in a 3-year WC-SW-NTF rotation is compared to 3-year rotations of WW-SW-UTF and WT-SW-NTF (acronyms are defined below). Note that SW follows WC, WW, and WT and that a 13-month fallow period occurs after SW in all three rotations. In Study 2, canola is grown in a 4-year rotation of WC-NTF-WW-NTF and is compared to WP-NTF-WW-NTF as well as a 2-year WW-UTF check. Spring canola is substituted for WC when adequate WC stands are not achieved. Both experiments have gone through full rotation sequences; thus, all crops are truly "in rotation". Agronomic data collected from these experiments includes: soil water dynamics from all phases of all rotations, foliar and root diseases, weed ecology, and grain yields. Soil microbial activity is currently being assessed in both canola rotations using DNA sequencing (Schlatter and Paulitz, see next abstract) and PLFA methods (Hansen, Rieser, Huggins). In addition, mycorrhizal inocula to enhance/promote soil microbial biomass in canola and subsequent crops are being evaluated. Such data can only be obtained through long-term cropping systems experiments. Schillinger and colleagues have published several scientific journal articles on these topics in the past three years and more publications are expected as we more fully explore canola rotations for Washington's drylands.

Acronyms used: NTF, no-till summer fallow; PLFA, phospholipid fatty acid analysis; SW, spring wheat; UTF, undercutter-tilled summer fallow; WC, winter canola; WP, winter pea; WT, winter triticale; WW, winter wheat.

# Yield Decline of Wheat After Canola: In Search of a Microbial Cause

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[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

In a series of replicated field trials over six years in the Reardan area, spring wheat grown after winter canola had an average 17% yield decrease compared to when grown after winter wheat (Schillinger and Paulitz, 2018, Field Crops Research 223: 26-32). We could not explain this with diseases, nutrients, weeds, or water use. We postulated that canola may either favor a microbial community deleterious to wheat or may decrease beneficial microbes that are important for wheat health (Hansen et al., 2018, Applied Soil Ecology 130:185-193). We attempted to answer this question by sampling the DNA from the rhizospheres of wheat and canola from fields in Douglas and Adams County (see 2018 Field Day Abstracts page 50) but did not come up with a "smoking gun". Many of the fungal and bacterial communities on the roots of wheat and canola were in common, but we could detect some differences. We now have an opportunity to address this question again in a long-term cropping systems project near Ritzville (see previous abstract) where we are experiencing this same yield reduction of wheat after canola.

**The term "rhizosphere soil" refers to soil that adheres to the roots of plants as seen here with winter canola. Photo by Jeremy Hansen, USDA-ARS.**

In the spring of 2019 (and planned again for 2020), we sampled bulk and rhizosphere soils of actively-growing spring wheat following canola, winter wheat and winter triticale. DNA will be extracted from the samples and sequenced with Illumina MiSeq. We will analyze the bacterial and fungal communities to identify differences among the three rotations. This will complement the phospholipid fatty acid analysis which is underway concurrently by Jeremy Hansen and colleagues. We hope to understand how canola may impact soil health, both positively and negatively. By understanding the cause of this phenomenon, we can understand the conditions under which it is a problem and possibly how it can be mitigated.

## Dual Purpose Winter Canola Grazing and Seed Harvest

ISAAC MADSEN[1] AND STEVE VANVLEET[2]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]WSU EXTENSION

In order to get the most out of a canola crop many farmers and researchers have been interested utilizing early seeded winter canola as a 'dual purpose' crop. The 'dual purpose' canola would be planted in mid or early summer, grazed in the fall, and taken to harvest in the following spring. However, the effect of fall grazing on the winter survival of canola is unknown. In the fall of 2017, a winter grazing trial was established near Dusty, WA. The canola was planted with a hoe style drill into good moisture on July 19th 2017. The field was divided into 3 pastures. Cattle grazing began in paddock 1 on September 15th and were moved to a second paddock 2 on September 26th, the cattle grazed through pasture 2 much faster than pasture 1, and where moved pasture 3. The grazing in pasture 2 was heavier than pasture 3 and the stand in pasture 2 appears to have been more damaged than pasture 3 (Fig. 1). The canola was harvested the following July with a Wintersteiger plot combine. One harvest swath was cut per pasture ranging from 150-300 ft in length and 5 ft wide (Table 1). Weight gain on cattle was estimated by weighing a sub sample of steers before and after they had grazed the pastures. Weight gain on the steers was used to estimate the economic benefits of grazing. Further work should be conducted in replicated trials, lending a higher degree of certainty to the results.

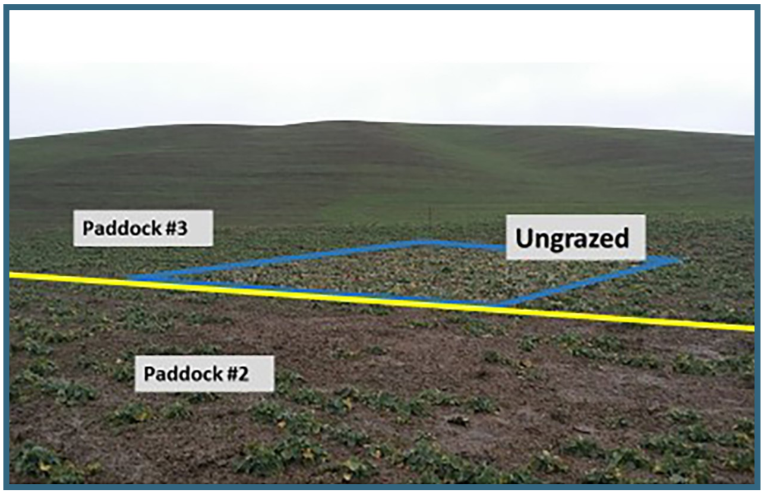

**Figure 1. Ungrazed canola, heavily grazed canola (Paddock #1), and lightly grazed canola (Paddock #2).**

**Takeaways:** There appears to be economic potential for grazing winter canola in the fall following seeding. Light grazing of winter canola appears to do little damage to the following canola seed yield, but grazing appears to damage canola yield.

**Table 1. Seed yield and cattle gain from canola grazing.**

| Treatments | Yield (lbs/a) | Elevator price/lb canola seed | Economic value of canola seed | Grazing pressure (46 head) | Economic value for grazing cattle (ADG) | Total Economic Return ($/a) |
|---|---|---|---|---|---|---|
| Pasture 1 | 2464 | $0.129 | $317.80/a | Heavy | 197.34 | 515.14 |
| Pasture 2 | 2143 | $0.129 | $276.45/a | Severe | 197.34 | 473.79 |
| Pasture 3 | 3322 | $0.129 | $428.58/a | Light | 157.87 | 586.45 |
| Ungrazed | 3384 | $0.129 | $436.52/a | None | 0 | 436.52 |

# WSU-WOCS Extension & Outreach: The Link from Research to Stakeholders

Karen Sowers[1], Dennis Roe[1], Aaron Esser[1], Ian Burke[1], Rachel Bomberger[2], Scot Hulbert[2], Bill Schillinger[1], and Tim Paulitz[3]
[1]Dept. of Crop and Soil Sciences, WSU; [2]Dept. of Plant Pathology, WSU; [3]USDA-ARS

After nearly twelve years of field, greenhouse, and laboratory research, the Washington State Oilseed Cropping Systems (WOCS) project has compiled a significant volume of data and results that are tremendously valuable to stakeholders in Washington state and surrounding states. The catch is how to most effectively share all we've learned, and that is where the Extension and outreach portion of the WOCS program plays an ongoing, and critical role. Field tours are a traditional method to convey information, but we have found that a wide range of communication is key to reaching more people and being the 'go to' resource when growers, crop consultants, and others have questions about anything oilseed related. The WOCS website (www.css.wsu.edu/oilseeds) contains information ranging from variety trial results to Extension publications to presentations. Facebook (WSU Oilseeds) has been effective to announce upcoming events and current field reports, and emails, phone calls, farm visits, radio interviews, 'stop 'n' talk' field tours, and texts are a year-round means of staying in touch with stakeholders. We are part of the Dryland Crops Team at WSU, the WA Oilseed Commission, and the PNW and U.S. Canola Associations. The annual WOCS oilseed workshops were a success once again, with 253 individuals attending the two locations, and 115 of those were first-time attendees (Fig. 1). Outreach beyond Washington state has strengthened collaboration between PNW university colleagues. The culmination of all that the WOCS team has produced, along with neighboring universities, will be the publication of a PNW Canola Production Guide. Canola acreage increased again in 2018 in WA (65,000 acres) and the 4-state PNW region (230,000 acres). We believe in order for that trend to continue, the oilseed research and Extension efforts of the WOCS project needs to strive to meet the educational needs of all involved in the oilseed industry in Washington state.

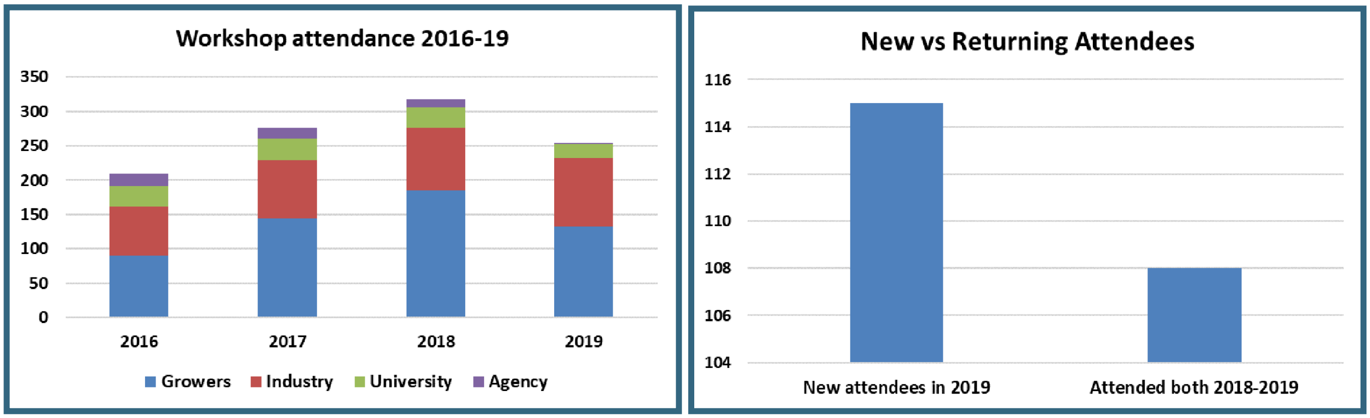

**Figure 1. Attendance trends at WSU-WOCS Oilseed Workshops (left), and first-time attendees in 2019. (right).**

# Soil Nitrogen and Water Relations with Winter Canola Nitrogen Use Efficiency

Marissa Porter, Isaac Madsen, William Pan, William Schillinger, and Haiying Tao
Dept. of Crop and Soil Sciences, WSU

Nitrogen (N) losses from fertilizers are an abundant pollutant in agricultural regions world-wide. Maximizing nitrogen use efficiency (NUE) is critical to reduce adverse environmental effects of fertilizer and obtain an economic return on inputs.

Winter Canola (*Brassica napus* L.) has an N requirement higher than wheat (*Triticum aestvum* L.) but has demonstrated limited responses to N fertilizer in the inland Pacific Northwest (iPNW). Nitrogen rate and timing trials were conducted at four sites during the 2017-18 crop year. Nitrogen was applied as surface granular urea at three timings of fall, spring, and split application, with split being 50% applied in fall and 50% in spring, in five rates from 0 to 240 kg N ha$^{-1}$. Soil samples were collected in the fall and spring prior to fertilization and post-harvest, then analyzed for N and moisture content. Spring plant samples and harvest yield and biomass data was collected, with plant and seed components analyzed for N content. Nitrogen use efficiency calculations for each season determined that NUE declined with increased rates of fertilizer. Maximum yield and nitrogen use efficiency (NUE) both increased with increased available water, whereas unit N requirement, the inverse of NUE, diminished with increased water availability. Ideal unit N requirements are between 0.05 and 0.09 kg Ns kg seed yield$^{-1}$. Our research findings suggest that residual N measurements to 180 cm soil depth and considering the local water regime are the most important factors to consider when making N management decisions for winter canola.

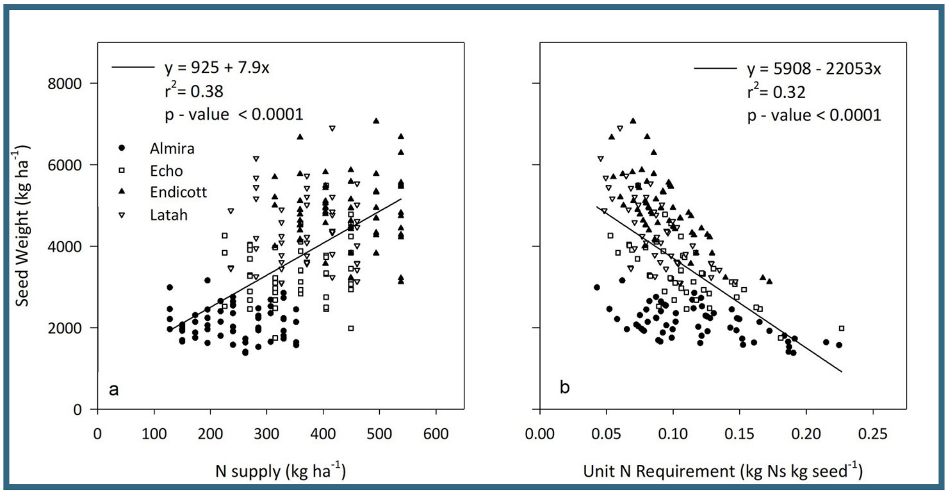

**Figure 1. Seed weight in relation to (a) N supply (fall residual N + spring fertilizer N + mineralized N) (b) unit N requirement (N supply/ seed weight) at 2017-18 winter canola sites .**

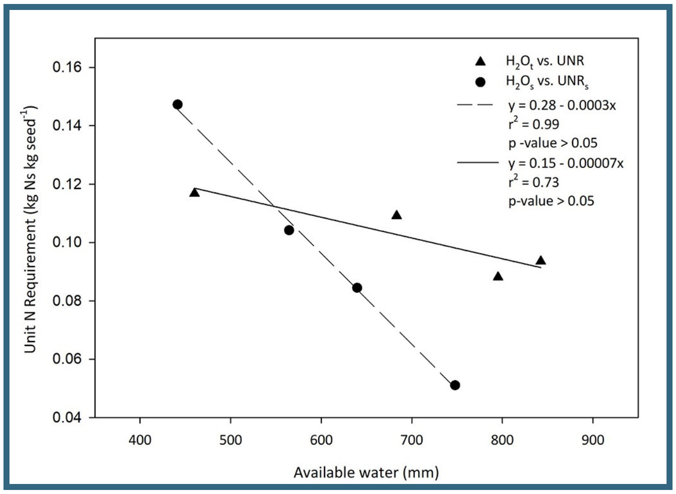

**Figure 2. Mean fall and spring unit nitrogen requirements (Ns/Gw; Nss/Gw) in response to total available water ($H_2Ot$; fall soil water + total season precipitation) and spring available water ($H_2Os$; spring soil water + spring precipitation) for 2017-18 winter canola sites. Data points represent averages across different nitrogen treatments across sites.**

# Winter Canola Response to Nitrogen Rate and Timing in Semiarid Mediterranean Conditions

MARISSA PORTER, ISAAC MADSEN, WILLIAM PAN, WILLIAM SCHILLINGER, AND HAIYING TAO
DEPT. OF CROP AND SOIL SCIENCES, WSU

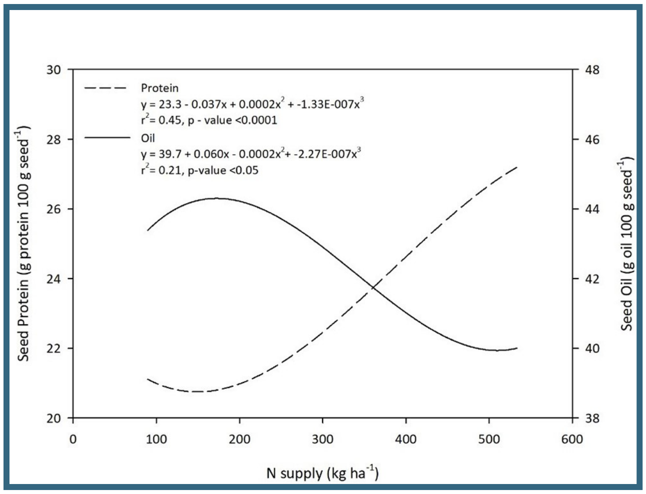

**Figure 1. Seed protein and oil concentrations in response to nitrogen supply (fall residual N + spring fertilizer N + mineralized N) at 2016-17 and 2017-18 winter canola sites.**

Integrating a new crop into a cropping system requires an understanding of nutrient use, specifically on the rate and timing of fertilizer applications in relation to soil type and climatic conditions. In the semi-arid dryland region of the inland Pacific Northwest (iPNW) where wheat (*Triticum aestivum* L.) covers 60% of the rainfed agricultural area, winter canola (*Brassica napus* L.) offers an economically viable rotation to wheat, providing breaks in pest and disease cycles and soil health benefits. Production in Washington state has increased from 4,000 to 28,000 hectares in the recent decade, yet little regional fertility research has been conducted (NASS, 2018). With a higher nitrogen (N) requirement and a lower nitrogen use efficiency (NUE) than wheat, canola requires unique N management to maximize economic return on fertilizer while minimizing environmental losses. Nitrogen rate and timing studies were conducted over two years at seven locations across the different precipitations zones of the iPNW. Nitrogen was applied as surface granular urea, with six rates from 0 to 240 kg N ha$^{-1}$ applied in fall, spring and split applications. There was no yield response to N application at six of the seven sites, suggesting that the high N uptake efficiency of canola and high N content of soils (86-182 kg inorganic N ha$^{-1}$) limited yield responses to applied N. Nevertheless, seed quality was affected by N, with increasing rates and later application timings leading to higher protein and lower oil content. Additionally, a relationship between temperature during flowering and seed quality was observed, with the ratio of seed oil to protein decreasing as average maximum May temperature increased. This research suggests that N management decisions should be conservative and made with the end uses of canola in mind, specifically whether maximizing protein or oil content is more desirable.

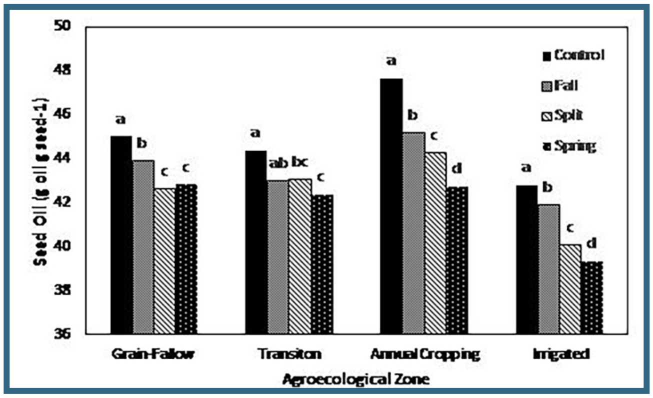

**Figure 2. The relationship between seed oil content and timing of N application for the different agroecological classes. Rates of N are averaged across the various timings.**

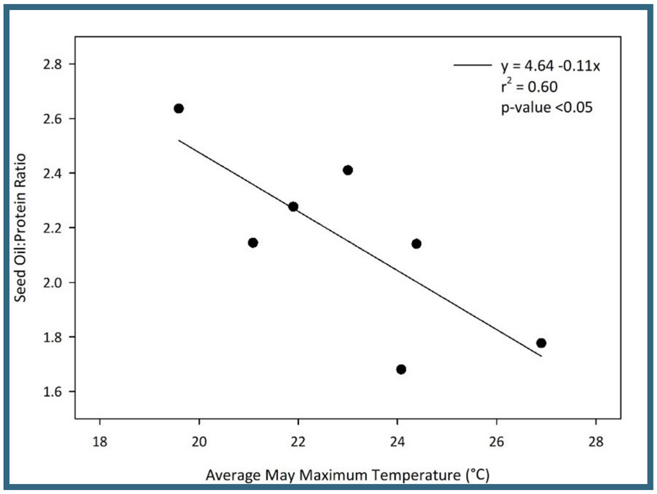

**Figure 3. Average seed oil: protein ratio in response to average May maximum temperature at winter canola sites in the 2016-17 and 2017-18 crop year.**

# Tissue Test and Foliar Applications of Micronutrients to Winter Canola

ISAAC MADSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

There are many questions surrounding micronutrients in canola production. In general micronutrients have been studied far less than macronutrients in canola production. The goals of our research were to (1.) evaluate the effects of foliar B, Zn, and Mo applications on canola and (2.) to look for varietal variation in micronutrient uptake. Foliar applications of B, Zn, and Mo were made in the fall when the winter is in the rosette stage and in the following spring at bolting. As can be seen from the initial results micronutrient applications did not increase yield, and at bolting applications appeared to damage yield (Fig. 1). The applications at bolting may have caused injury to the plant as B is known to be toxic to plants at high concentrations. Additionally tissue samples were taken from the canola variety trials and inter-species variation in nutrient uptake. No significant differences between canola varieties were found. However, inter-field variation was found to be high indicating that any difference between varieties may be masked by the heterogeneity of the soil supply of micronutrients as can be seen in the example of B uptake (Fig. 2).

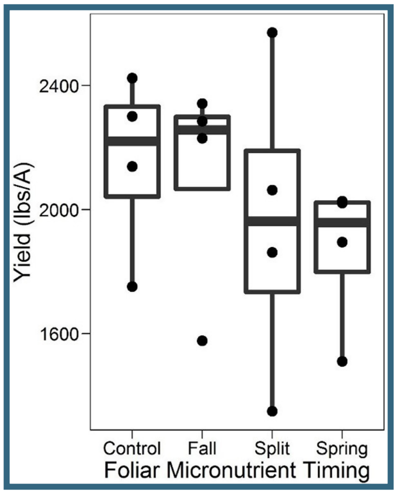

**Figure 1. Winter canola yield response to fall, at bolting, and application of foliar B, Zn, and Mo.**

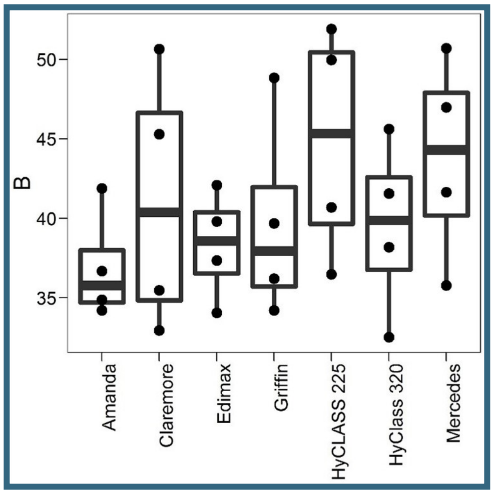

**Figure 2. B uptake by different canola varieties within the same field. Demonstrating the effects of inter-field variability out weight the effects of variety in this particular instance.**

# Camelina: Ten Years of Cropping Systems Research at Lind

BILL SCHILLINGER, JOHN JACOBSEN, STEVE SCHOFSTOLL, AND BRUCE SAUER
DEPT. OF CROP AND SOIL SCIENCES, WSU LIND

**Overview:** Camelina is a short-season annual oilseed crop in the *Brassicaceae* family. Interest in camelina has increased substantially during the past 15 years because the oil is an excellent feedstock for producing low-carbon-emission biofuel and has a unique fatty acid profile as a potential edible oil. Camelina has been promoted as an alternative crop in low-precipitation dryland regions because of its low fertilizer requirement and drought tolerance. A 10-yr field experiment was conducted from 2008-2017 at the WSU Dryland Research Station near Lind, Washington to compare a 3-yr winter wheat (WW)-spring camelina-summer fallow (SF) rotation with the traditional 2-yr WW-SF rotation. Annual crop-year (Sept. 1-Aug. 31) precipitation ranged from 7.6 to 14.8 inches and averaged 11.1 inches. Camelina seed yield ranged from 302 to 1049 lbs/acre and averaged 574 lbs/acre (Fig. 1). Mean WW yield of 40 bu/acre in the 3-yr rotation was significantly lower ($p$=0.046) compared to 43 bu/acre in the 2-yr rotation. Soil profile water was significantly lower ($p$<0.001) after harvest of camelina compared to after WW harvest in the 2-yr rotation. This soil water reduction was consistently measured throughout the ensuing 13-month fallow cycle. There are no labeled in-crop broadleaf weed herbicides for camelina and populations of Russian thistle and tumble mustard were higher in camelina than in WW. This was likely a factor in the deep extraction of soil water in the camelina plots to a depth of six feet. Data from this study suggest that, with current varieties and management practices, camelina is not yet agronomically or economically stable or viable in a 3-yr WW-camelina-SF rotation in the low-precipitation (<12 inch annual) rainfed cropping region of the Inland Pacific Northwest.

**Figure 1. The lowest camelina yield of 302 lbs/acre occurred in 2014 (left) when only 7.6 inches of precipitation occurred during the crop year. Note the infestation of Russian thistle. The highest camelina yield of 1049 lbs/acre (right) was in 2016 when 14.8 inches of precipitation fell during the crop year.**

**Conclusions:** Regional farmers did not consider camelina either agronomically or economically attractive. Growing camelina in a wheat-based rotation did not enhance the subsequent WW yield compared to the 2-yr WW-SF rotation. Although the ability to effectively control grass weeds in camelina is a big benefit, the lack of in-crop broadleaf herbicides as well as lack of federal crop insurance are detriments. Interest in growing camelina would likely improve as new varieties, agronomic and management practices, and government programs are developed and refined. For example, during the past ten years, winter canola production in the PNW dryland region has rapidly expanded due to a focused multidisciplinary research and extension effort by university, USDA, and private-company scientists, the development of varieties with herbicide tolerance/resistance and other attributes, and the availability of federally-subsidized crop insurance.

## WSU-WOCS Large-Scale Canola Variety Trials

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[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]DEPT. OF PLANT PATHOLOGY, WSU; [3]VITERRA/PACIFIC COAST CANOLA; [4]OSU EXTENSION

A major component of the Washington State Oilseed Cropping Systems (WOCS) Project since 2016 is the large-scale, on-farm winter and spring canola variety trials. With canola acreage increasing annually in Washington state and the Pacific Northwest, the trials are valuable to growers and industry when making not only variety selection decisions, but the full gamut of production components that are part of having a successful crop.

Winter canola plots were established at Mansfield, Ritzville, and The Dalles, OR during Fall 2017. Spring canola trials were seeded in 2018 at Davenport, Ralston, and Walla Walla. The Dalles, OR site marked the first time a trial was located outside of WA state. Yield results from the winter trials were only significant at The Dalles. Soil type and moisture variability at Mansfield, and weed pressure and a soil moisture gradient across the plot area at Ritzville likely contributed to the wide range of yield but lack of significance. The hybrid 'Mercedes' had the highest yield at all locations. Harvest at Ritzville occurred on two dates due to variable ripening on one end of the field. The Substation fire at The Dalles interrupted harvest so it was also completed on two different dates. Tours at all three locations attracted 122 people. Attendees at a fall 'stop 'n' talk tour at the Ritzville site included growers, crop consultants, WSDA employees to learn about blackleg scouting, and insurance adjusters to see differences in crop establishment.

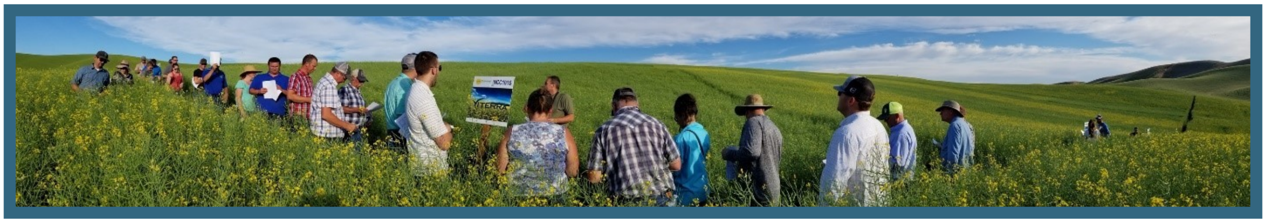

**Figure 1. Tours were held at all spring and winter canola variety trial sites. Photo from the Walla Walla spring canola site.**

Mean yield at the three spring canola sites ranged from 611 lbs/acre at Reardan to 2323 lbs/acre at Walla Walla, with similar yield trends between the entries. Low yield at Reardan can be attributed to the late planting date and high heat during flowering. Yield data from Dr. Dave Huggins, USDA-ARS, showed a 50 lb/acre reduction in spring canola yield potential for each day after April 12 that canola is planted (data not shown). Using that information, it can be calculated that 1500 lbs/acre more yield was possible at Reardan had field conditions allowed earlier seeding. There were consistent trends in flowering timing of the entries observed at all locations. NCC101S and HyCLASS 930 flowered 7-10 days earlier than the other entries, which is a factor to consider in variety selection if early spring heat is a concern. Ninety people attended tours at the spring canola sites, with 6-8 speakers at each. Representatives from the national USDA-RMA office attended two of the tours to interact with growers about establishing an insurance program for hybrid canola seed production.

**Yield results of 2017-18 On-farm Winter Canola Variety Trials**

| Variety | The Dalles[1] | | Ritzvile[2] | | Mansfield[3] | |
|---|---|---|---|---|---|---|
| | lbs/acre | | | | | |
| Mercedes | 3,049 | a | 3,130 | a | 2,445 | a |
| Griffin | 2,785 | ab | 3,034 | a | 1,652 | a |
| HyClass 320 | 2,550 | bc | 2,583 | a | 1,929 | a |
| Edimax CL | ---- | ---- | 2,621 | a | 2,163 | a |
| Amanda | 2,494 | bc | 2,828 | a | 1,817 | a |
| HyClass 225 | 2,333 | c | 2,642 | a | 1,796 | a |
| Claremore | 2,241 | c | 2,857 | a | 1,722 | a |
| Mean | 2,585 | | 2,814 | | 1,932 | |
| Tukey $HSD_{(0.05)}$ | 375 | | ns | | ns | |
| CV (%) | 7.0 | | 12.1 | | 30.2 | |

[1] Planted Sept. 22, 2017, harvested July 16 and July 23, 2018.

[2] Planted Sept. 19, 2017, harvested July 21 and August 6, 2018.

[3] Planted August 24, 2017, harvested 7/26/18.

It is worth noting the depth and extent of collaboration and assistance throughout the growing season from the grower cooperators, industry, WSU and OSU field technicians, grad students, and faculty that was crucial to the success of the trials. Our deepest thanks to all!

Winter canola trials were not seeded in 2018 due to poor planting conditions. Spring canola trials are planted at Wilbur (Brunner farm), the Cook Farm in Pullman, and as of printing were slated for the WSU Wilke Farm near Davenport.

Many thanks to our 2017-18 cooperators: David Brewer, Rob Dewald, Curtis Hennings, Douglas Poole, Mark & Brendan Sherry, and Paul Williams.

Seed provided by Bayer CropScience, BrettYoung, Caldbeck Consulting, Nutrien Ag Solutions, Croplan by Winfield, Dow AgroSciences, Kansas State University, Rubisco Seeds, Spectrum Crop Development, and University of Idaho.

**Yield results of 2018 On-farm Spring Canola Variety Trials**

| Variety | Ralston[1] | | Reardan[2] | | Walla Walla[3] | |
|---|---|---|---|---|---|---|
| | ———— | ———— | lbs/acre | ———— | ———— | ———— |
| NCC 101S | 1,955 | a | 774 | a | 2,417 | a |
| HyClass 930 | 1,864 | ab | 696 | a | 2,608 | a |
| InVigor L233P | 1,793 | bc | 693 | a | 2,433 | a |
| BY 6080 RR | 1,639 | c | 557 | a | 2,410 | a |
| BY 5545 CL | 1,694 | c | 529 | a | 2,319 | ab |
| DG 200 CL | 1,631 | c | 508 | a | 2,253 | ab |
| HyClass 730 | 1,709 | bc | — | — | — | — |
| Nexera 2024 CL | 1,291 | d | 515 | a | 1,824 | b |
| Mean | 1,710 | | 611 | | 2323 | |
| Tukey HSD$_{(0.05)}$ | 223 | | 285 | | 533 | |
| CV (%) | 4.8 | | 19.4 | | 9.8 | |

[1] Planted April 9, harvested August 6

[2] Planted May 11, harvested September 3

[3] Planted March 30, harvested August 1

## Monitoring Pea Weevil (*Bruchus pisorum*) in Pulse Crops

Dale Whaley
WSU Extension

A quiet transformation is taking place in grain fields across central Washington. A mere decade ago, winter peas were once thought has a specialty crop with marginal acres being planted. The number of planted pea acres in Adams, Douglas, Grant and Lincoln counties for 2017 has increased to 18,182 (6,684 non-irrigated/11,498 irrigated) acres (FSA Data). The ability of peas to fix atmospheric nitrogen makes it a great rotational crop with the regions winter wheat crops. Winter wheat after winter peas with no applied fertilizer yielded 59.0 bu/acre with a grain protein of 10.8% (Howard Nelson, CWGG). Unfortunately, both winter and spring peas are under attack by the Pea Weevil, *Bruchus pisorum*. Heavy infestation of the Pea Weevil can reduce the pea seed to shells thereby severely impacting yields. A second impact to feeding by pea weevil is that it can actually make plants more susceptible to aphids and aphid-transmitted viruses.

A total of six fields where identified within the Waterville area and an additional six fields spanning from Davenport down to Lind. Funding for this project comes from Highline Grain Growers. The overall goal of this research project is to better understand the severity of this pest across our region, better define when this pest should be targeted for control, if any, and to alert pea producers about the size and location of damaging insect pest populations in order to aid in early detection and management efforts for this pest. The "action" or "treatment" threshold for this pest is (1 adult in 25 sweeps).

The first three weeks of sampling resulted in zero weevils from either area. After adjusting the sampling time back 2 additional hours, weevils started to be detected. Weevil numbers went from 0 to 21 in 1 week with the later sampling time frame. Therefore, time of sampling may be an important factor in determining pest activity and "action" or "treatment" thresholds. It appears that pea weevil is more common than we had originally anticipated. Producers will want to keep a watch out each year for this pest.

## Investigating Agronomic Practices for Dryland Quinoa Production in Eastern Idaho

XI LIANG AND RUI YANG
DEPT. OF PLANT SCIENCES, UI

Quinoa production area in eastern Idaho has been increasing rapidly in recent years, i.e., from a few acres in 2014 to 3,500 acres in 2018. Despite this rapid increase, best management practices for quinoa production have yet to be determined in this area. The objectives of this study were to evaluate the suitability of our regional environment for quinoa production and the effect of row spacing on weed competition. A dryland experiment was conducted in Tetonia in eastern Idaho in 2018. The quinoa varieties Cherry vanilla, French vanilla, and Biobio were planted at 7-, 14-, and 21-inch row spacing and arranged in a randomized complete block design with four replicates. Experimental plots of 10 by 15 feet were established on June 6 and harvested on September 12 (Fig. 1). In early July, each plot was evenly divided into weed-free and weedy subplots. Weeds were manually removed in weed-free subplots. Weed biomass was harvested between quinoa rows from each weedy subplot in July. Leaf area index (a measure of plant canopy structure) was measured from each weed-free subplot in mid-August. In Tetonia, total rainfall from May to September was 9.6 inches, and there were only eight days of daily maximum air temperature above 86°C (Fig. 2). Tetonia would likely be a suitable area for quinoa production since temperatures above 95°F for a long time could cause pollen sterility and severe yield loss in quinoa. In the weedy subplots, redroot pigweed, shepherd's purse, and cutleaf nightshade were the most prevalent weeds. Total weed biomass collected between quinoa rows was significantly less at the 7-inch than the 21-inch row spacing (Fig. 3A), but no difference between varieties was found. In the weed-free subplots, leaf area index of quinoa planted at 7-inch row

**Figure 1. Plants were 2- to 3-foot tall 7 weeks after planting under dryland conditions (photo by Joseph Sagers on July 31, 2018).**

spacing was greater than 14- and 21-inch (Fig. 3B). Quinoa plants were thus able to develop a dense canopy under narrow row spacing to suppress weed growth.

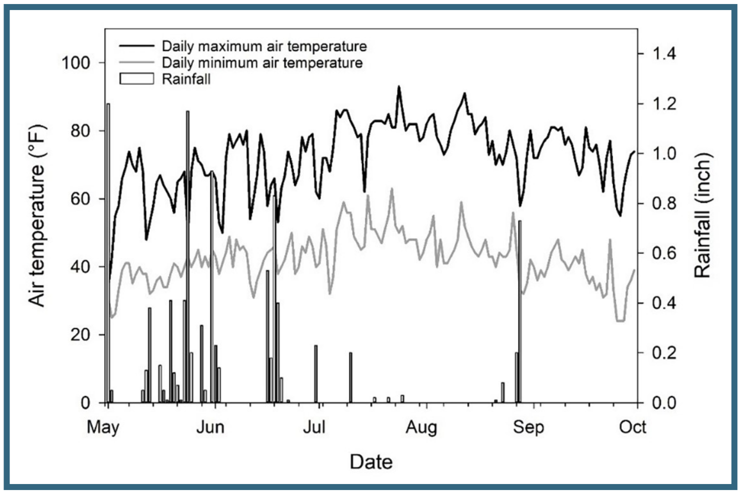

**Figure 2. Daily maximum (black line) and minimum (grey line) air temperature and rainfall (vertical bar) during the growing season of 2018 in Tetonia, ID (https://www.usclimatedata.com).**

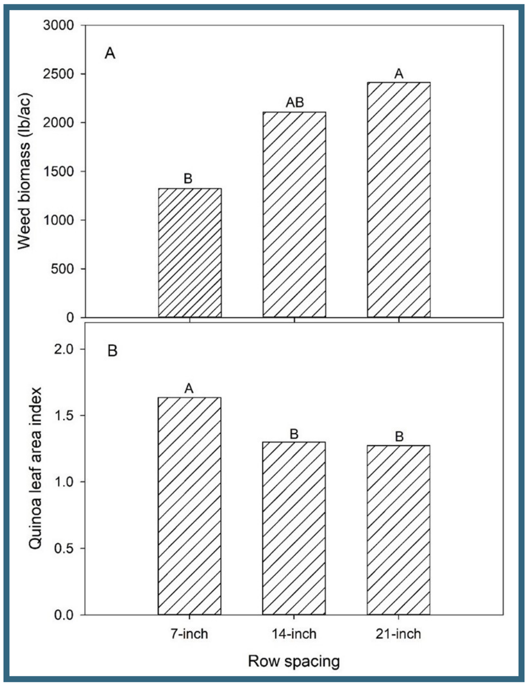

**Figure 3. Weed biomass (*P* = 0.044) collected between quinoa rows and quinoa leaf area index (*P* = 0.005) were affected by row spacing in Tetonia in 2018.**

## Effect of Seeding Depth, Fertilizer Application, Seeding Rate, and Seeding Date on the Agronomic Performance of Two Winter Pea Cultivars

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Diversification and intensification of existing wheat-based cropping system in the Inland Pacific Northwest is required to develop a resilient system to deal with seasonal variability and eminent climate change issues. Winter pea is a crop that could potentially be incorporated into the existing cropping system due to several advantages over spring crops. Winter pea utilizes less water than spring cereals, has a higher yield potential than spring pea, provides nitrogen to following crops, can be used as a forage crop and as an option in cover crop mix. However, to be successful, the crop must efficiently survive the winter and produce a yield superior to spring legumes.

**Photo 1. Early planted plots in Genesee, ID approaching harvest.**

Field trials were conducted at Genesee, ID and St. John, WA, during the 2017-18 growing season, to evaluate effects of seeding depths (2 and 4 in), phosphorus and sulfur fertilizer application at 20 lb/A each (with and without), seeding rates (6, 8 and 10 seeds per ft$^2$) and cultivars (Blaze and Windham) on performance of winter pea that were planted in early, mid and late fall (Mid-Sept., Early Oct. and Late Oct. respectively).

The results were similar between locations with seeding date having the greatest impact on performance. Early planting was optimal, producing the highest yield at both locations, but late planting also produced acceptable yield (Fig. 1). There was adequate seed zone moisture at planting in the fall of 2017, but this data suggests that dormant seeding might be an option in dry years. Deeper seeding was not advantageous as the experiments were conducted in annually cropped areas and in both cases were following a spring wheat crop. However, deeper seeding is necessary in the crop-fallow zones where there is stored moisture during the fallow period. Fertilizer application did not show any yield advantage, with an average of 2,105 lb/A without fertilizer and 2,063 lb/A with phosphorus and sulfur fertilization at planting. A seeding rate of 10 seed per $ft^2$ produced the greatest yield, but higher seeding rates should be explored. Both Windham and Blaze had similar performance although Blaze seeds were larger and had higher protein content.

**Photo 2. Late planted plots ready to harvest at St. John, WA.**

This study suggests that winter pea is a potential option to include in current cropping system only if suitable agronomic strategies are adopted. Further studies would help to validate the conclusions of this study.

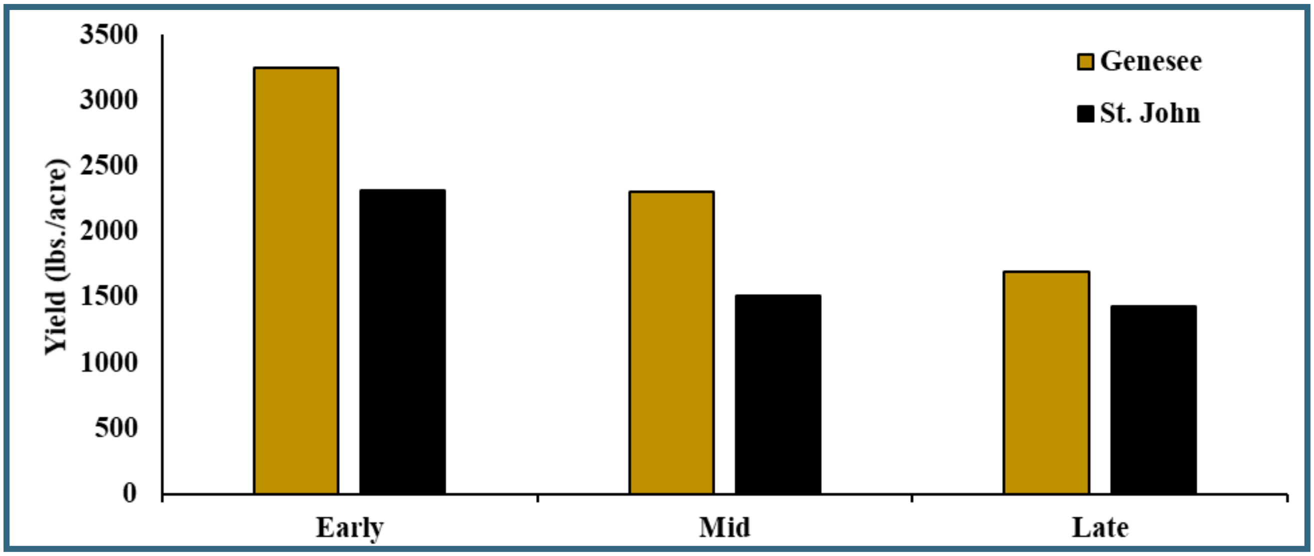

**Figure 1. Yield of winter pea at different planting times at Genesee, ID and St. John, WA.**

# Part 3. Pathology, Weeds, and Insects

## Resistance to Group II Herbicides in Downy Brome

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Downy brome (*Bromus tectorum*) also known by cheatgrass is a troublesome winter weed species that thrives in semi-arid regions of the Pacific Northwest (PNW) where winter wheat is the predominant crop. This weed species germinates normally in the fall but it can germinate later, a characteristic that allows this species to be highly competitive with wheat. Infestations of downy brome can reduce winter wheat yields largely depending on weed density.

Its postemergence control in winter wheat is, in many cases, reduced to fall or/and spring application of group II herbicide such as, pyroxulam, propoxycarbazone-sodium, mesosulfuron, sulfosulfuron, or imazamox because of their selectivity and effectiveness. The repetitive use of herbicides with the same mode of action (inhibitors of the enzyme acetolactate synthase (ALS), a key enzyme in plant metabolism) may have selected for resistant populations of downy brome in Oregon that pose an additional challenge to wheat growers.

In spring 2018, we evaluated in the greenhouse the existence of resistance to group II herbicides in several downy brome populations of northeastern Oregon coming from wheat fields. Five populations of downy brome were collected in the summer of 2017 from wheat fields in Echo (Pop 6), Ione (Pop 5), Athena (Pop 4), Adams (Pop 3) and Pendleton (Pop 2). Before initiating the resistance study, a screening test was conducted on each population, using approximately 100-200 seeds/plants per population to detect control problems with group II herbicides using the label rate. The herbicides used were Osprey® (mesosulfuron), Olympus® (propoxycarbazone), PowerFlex® (pyroxulam), and Beyond® (imazamox) as group II and Assure® II (quizalofop)(10 fl oz/ac), as group I herbicide, for comparison.

The experimental design for the resistance study was a randomized complete block (blocked by population) with treatments replicated six times. A sixth downy brome population from 2010 (Pop 1) was included in the study as the control (susceptible population). Plants were treated at 0, 0.5X, 1X, 2X, and 4X. The X rate of PowerFlex, Osprey, Olympus, and Beyond was 2, 4.75, 0.9 and 4 fl oz ac$^{-1}$ respectively. The level of resistance (Resistant Index (RI)) was determined by calculating an R/S ratio ($I_{50}$ of a resistant (R) biotype divided by the $I_{50}$ of a susceptible (S) biotype).

All evaluated populations had resistance to one or more herbicides (Fig. 1). Population 2 collected from Columbia Basin Ag. Research Station (CBARC) showed resistance to all group II herbicides evaluated but Beyond. The resistance of this population to several herbicides was very high (RI > 10), it did not show response to increased rate of PowerFlex (Photo 1a). Population 3 collected from a neighbor field to CBARC was susceptible to Olympus, Beyond, and PowerFlex but showed a light resistance to Osprey (RI = 1.5). Population 4 was resistant to all herbicides evaluated but PowerFlex (Photo 1b). Population 5 was resistant to all herbicides evaluated but Osprey.

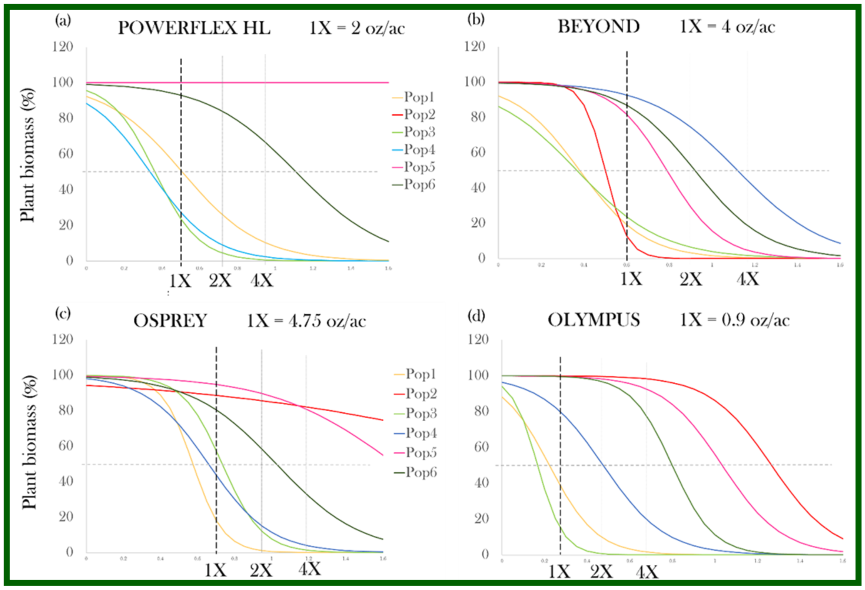

**Figure 1. Dose-response curves of relative downy brome fresh biomass per plant 3 weeks after treatment for (a) Powerflex, (b) Beyond, (c) Osprey, and (d) Olympus. The grey dashed horizontal line indicates 50% of control, the black dashed line indicates the recommended rate (1X) for each herbicide, the dark grey dotted line indicates two times the recommended rate, and the light grey dotted line indicates four times the recommended rate.**

Population 6 was resistant to all herbicides evaluated. Population 1 was susceptible to all the herbicides evaluated but PowerFlex (Pop 3 was used as the susceptible for this herbicide to calculate the RI). The six populations evaluated were susceptible to Assure II (quizalofop).

In conclusion, we obtained that resistance to group II herbicides in downy brome populations seems to be common in northeastern Oregon.

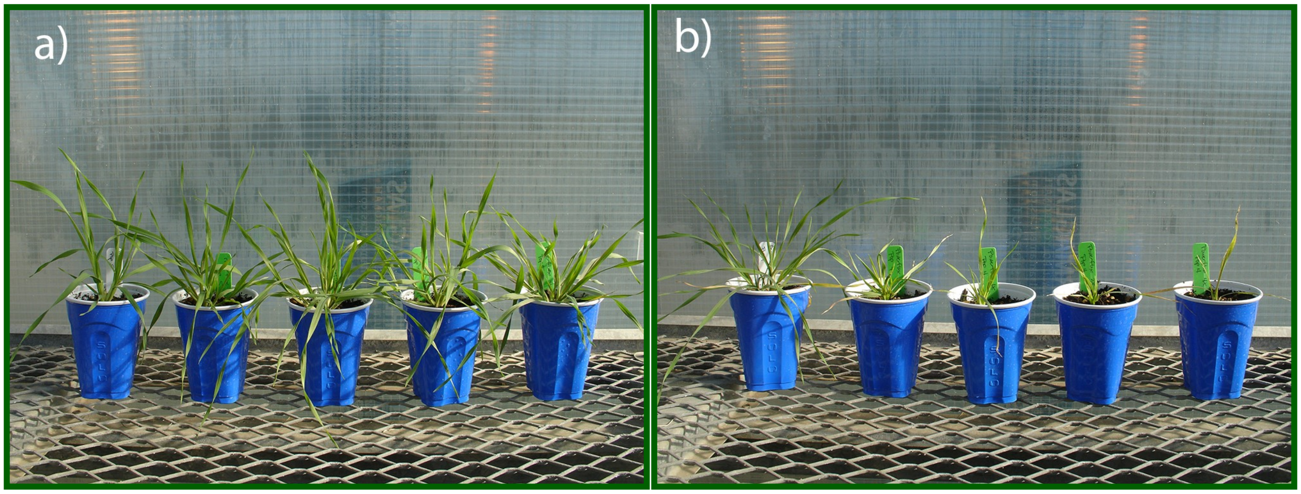

**Photo 1. a) High resistance to PowerFlex® (pyroxsulam) shown by Population 2, b) Susceptibility to PowerFlex® shown by Population 4.**

## Cereal Rust Management and Research in 2018

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In 2018, wheat stripe rust developed to a severe epidemic in the Pacific Northwest (PNW). The severe stripe rust epidemic was accurately forecasted using prediction models in March and monitored in fields throughout the crop season. Rust updates and advises were provided in a timely manner to growers for implementing appropriate disease management based on the forecasts and field surveys. Yield losses up to 71 percent were observed on susceptible checks and 0-23 percent (average 10 percent) on commercial varieties of winter wheat; and up to 66 percent on susceptible checks and 0-48 percent (average 14 percent) on commercial varieties of spring wheat in our experiment fields without fungicide application. The timely application of fungicides in the early crop season kept stripe rust under control, which saved more than 16 million bushels of wheat grain, about 70 million dollars at the cost of about 6 million dollars in Washington State alone. Nationally, wheat stripe rust occurred in 19 states in 2018, fewer than 2016 and 2017, and damage was less than the previous two years due to the dry and hot conditions of the late spring in the central Great Plains. Barley stripe rust occurred in California, Oregon, Montana, and Washington. Wheat leaf rust occurred in both western and eastern Washington and caused localized damage. Barley leaf rust occurred in western Washington, but not found in eastern PNW after the first occurrence in 2017. Stem rust of wheat and barley was absent in Washington. From stripe rust samples collected throughout the country, we identified 26 races (2 new) of the wheat stripe rust pathogen and 12 races (1 new) of the barley stripe rust pathogen. In Washington state alone, 22 races (2 new) of the wheat stripe rust pathogen and 9 races (1 new) of the barley stripe rust pathogen were identified. Using the advanced sequencing technology, we obtained high-quality genome sequence for a stripe rust pathogen isolate carrying the highest number of avirulence genes and identified effector genes as candidates for several avirulence genes. We evaluated more than 40,000 wheat, barley, and triticale entries for resistance to stripe rust in fields and about 3,000 of them also in the greenhouse and provided the data to breeding and other related programs. We collaborated with breeders in pre-releasing, releasing, and registering nine new wheat varieties. We completed the studies of mapping 17 genes for all-stage and/or high-temperature adult-plant resistance to stripe rust in three important PNW winter wheat varieties (Madsen, Eltan, and Skiles) and determined the genetic mechanisms of durable resistance. We advanced 40 crosses of winter wheat to the $F_5$ generation and obtained initial stripe rust data for identifying and mapping new stripe rust resistance genes. We tested 31 fungicide treatments in fields for control of stripe rust on both winter and spring wheat; and 24 winter and 24 spring wheat varieties for their yield loss and fungicide response. In 2018, we published 26 journal articles and 14 abstracts. The results and genetic resources produced from our research have been used to develop stripe rust resistant varieties, registering new fungicides, and guiding the control of stripe rust.

## Population Dynamics of Wheat Root Pathogens Under Different Tillage Systems in Northeast Oregon

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No-till or direct-seeding can be described as seeding directly into the crop stubble from the previous season without use of tillage. A reduction in tillage can result in many benefits, including increased soil organic matter, increased water holding capacity, and reduced fuel costs. However, the effect of no-till and reduced tillage on crop root disease profiles is poorly understood. To study the effect of tillage on disease dynamics, soil samples were collected from commercial wheat fields representing a wide range of tillage strategies in fall 2016 and fall 2017. Because precipitation might affect soil-borne diseases, wheat fields located across a diverse gradient of precipitation zones of the dryland Pacific Northwest were selected. *Fusarium* spp., *Pythium* spp., and *Rhizoctonia* spp. were quantified from soil samples using soil dilution plating and quantitative PCR (qPCR) assays. Results of dilution plating showed that the colony counts of *Fusarium, Pythium,* and *Rhizoctonia* at the genus level were negatively associated with tillage. However, the same patterns were not observed when specific causal agents of *Fusarium*, *Pythium*, and *Rhizoctonia* that are known to be pathogenic on wheat were quantified with qPCR. Furthermore, precipitation affected the population density of some fungal pathogens (*F. culmorum, P. ultimum,* and *R. solani* AG-8). Results of this study indicate that the benefits of adopting reduced tillage likely outweigh potential risk for increased root disease.

## Smooth Scouringrush Control in No-till Systems in the Inland Pacific Northwest

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Over the past 15 years, smooth scouringrush (*Equisetum laevigatum* A. Braun) has spread into no-till cropland causing concern for growers. Crop competition from smooth scouringrush appears to effect pulse crops more than winter wheat, but for livestock consuming the plant either fresh or dry, it contains a thiamase enzyme that destroys vitamin B1 (thiamine) and causes B1 deficiency and possible equisetosis. Smooth scouringrush is a member of a prehistoric group of plants whose ancient relatives date back approximately 350 million years, nearly 200 million years before the appearance of modern flowering plants, and 300 million years before the evolution of grass plants. It is native to North America and is often found near streams and along roads where water collects. Plants are deep-rooted and spread mainly by rhizomes, but they also produce asexual spores. Stems are leafless and contain a high concentration of silica. Fertile stems have a spore-producing structure at the tip (Fig. 1).

**Figure 1. On the left, smooth scouringrush stems with spore-producing strobili at the tip. On the right, no-till fallow treated with RT 3 (center) or Rhonox (left edge) in May. Uncontrolled smooth scouringrush in the background.**

We initiated a five-year study in 2017 near Omak, WA to evaluate control of smooth scouringrush with Finesse (chlorsulfuron + metsulfuron) in a winter wheat/no-till fallow rotation. Chlorsulfuron is effective in controlling smooth scouringrush, but long-term control may require repeated applications. No-till fallow plots treated with Finesse in June 2017 remained nearly clean until crop harvest in 2018; however, no yield differences were found between treatments (Table 1). Amber herbicide (triasulfuron) is molecularly similar to chlorsulfuron and was applied during the crop phase in 2018. Rhonox (MCPA) was applied as a check treatment to control broadleaf weeds other than smooth scouringrush. Rhonox is effective as a burn-down treatment for smooth scouringrush, but does not control regrowth. Finesse will be reapplied in June 2019 to compare control from applications in two consecutive fallow years versus application in only one fallow year. Finesse is labeled in wheat or fallow, but carries interval restriction for planting back to durum wheat, barley, pulse crops, and canola.

**Table 1. Scouringrush control in wheat/fallow with Finesse – Omak, WA**

| Herbicide application timing[1] | | | | Scouringrush density[2] | | | |
|---|---|---|---|---|---|---|---|
| Fallow 2017 | Crop 2018 | Fallow 2019 | Crop 2020 | Summer 6-25-17 | Spring 5-25-18 | Summer 8-13-18 | Wheat Yield |
| | | | | -----------(stems/yd$^2$)----------- | | | (bu/A) |
| Finesse | Amber | Finesse | Amber | 217 a | 0 b | 0.2 b | 27 a |
| Finesse | Amber | Finesse | Rhonox | 168 a | 0 b | 0 b | 28 a |
| Finesse | Amber | Rhonox | Rhonox | 218 a | 0 b | 0 b | 32 a |
| Finesse | Rhonox | Rhonox | Rhonox | 190 a | 0 b | 0 b | 26 a |
| Finesse | Rhonox | Finesse | Rhonox | 227 a | 0 b | 0.1 b | 28 a |
| Rhonox | Rhonox | Rhonox | Rhonox | 196 a | 93 a | 212 a | 32 a |

[1] Finesse (chlorsulfuron/metsulfuron) applied at 0.5 oz/A with 0.33% NIS surfactant. Amber (triasulfuron) applied at 0.56 oz/A with 0.33% NIS surfactant. Rhonox (MCPA) applied at 34.6 oz/A in fallow and 24 oz/A in crop. Fallow treatments in 2017 were applied June 28, 2017. Crop treatments in 2018 were applied May 25, 2018.

[2] Values in each column followed by the same letter are not different ($\alpha=0.05$).

For control strategies in systems where herbicide residual would be a problem, we compared broadcast applications of RT 3 at 96 oz/A with rope wick applications of 75% v/v RT 3 (glyphosate). The broadcast RT 3 treatment applied in May 2018 near Omak, WA reduced stem density by 91% compared to the non-treated check (Fig. 1), whereas the same application in July at Reardan only reduced stem biomass by 4% of the check (Table 2). This difference may have been due to increased silica in the stems that reduced herbicide movement into the plant. The addition of Silwet® organosilicone surfactant improved efficacy of RT 3 at Reardan. The rope wick applications at both Omak and Reardan were intermediate in efficacy. This may have been partly due to not getting good herbicide contact on the stems. At Omak, some of the stems were lying flat on the ground and did not contact the wicks. At Reardan, a dense stand of smooth scouringrush may have limited all stems from contacting the wicks. These trials will be reassessed in 2019 for long-term effect.

**Table 2. Smooth scouringrush control comparing rope wick with broadcast herbicide treatments at Omak and Reardan, WA.**

| | | Smooth scouringrush control[2] | |
|---|---|---|---|
| Treatment[1] | Rate | Omak[3] | Reardan[4] |
| | | (% control compared to non-treated check) | |
| RT 3 – rope wick | 75% v/v | 68 b | 24 b |
| RT 3 – broadcast | 96 oz/A | 91 a | 4 bc |
| RT 3 + Silwet – broadcast | 96 oz/A + 0.25% v/v | na[5] | 56 a |
| Rhonox – broadcast | 48 oz/A | 10 c | 49 a |

[1] Treatments applied May 25, 2018 at Omak and July 5, 2018 at Reardan.

[2] Values in each column followed by the same letter are not different ($\alpha=0.05$). Comparisons are percent of the non-treated check plot means in each column.

[3] Omak treatments were assessed 45 days after treatment by counting living stems in two 2.7 $ft^2$ areas per plot. Non-treated check plots averaged 157 stems/$yd^2$.

[4] Reardan treatments were assessed 33 days after treatment by collecting all living tissue in two 2.7 $ft^2$ areas per plot. Non-treated check plots averaged 2.2 oz dry matter/$yd^2$.

[5] RT 3 + Silwet not applied at Omak.

## Understanding Dangerous Work: Implications for Pesticide Applicator Education in Idaho

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Pesticide application is central to farming and agricultural research in Idaho. A variety of factors contribute to the reasons pesticide applicators do not always work safely, resulting in long-term health and environmental risks. More than 8,000 licensed applicators in the state of Idaho apply pesticides on 13,182 farms (NASS, USDA, 2012). Pesticide use is highly regulated by federal and state government because of the potential significant and toxic effects if misused. It is well documented that pesticide accidents and drift occurrences can affect the health of workers and others who are inadvertently exposed to these potentially dangerous chemicals. The purpose of this qualitative study was to identify critical learning components and approaches that lead to the safe use of pesticides.

This study employed four focus group interviews with 24 pesticide applicators intended to elicit stories and effective learning mechanisms for pesticide safety. The study also included seven one-on-one interviews with experts to reach theoretical saturation of data categories, and also included a statewide survey of pesticide applicators to gather baseline data about the population of pesticide applicators in Idaho. Researcher observation was valuable in understanding the cultural context of pesticide applicators. In addition to categories that surfaced from theoretical sampling: *knowledge and learning, worker practices, worker beliefs and attitudes, and work environment,* four additional categories arose from the data: *changes over time, worker development, interfacing with the public, and dangerous work.* Data also illuminated pesticide applicator subculture by clarifying narrative, in the form of *exposure* and *non-exposure* stories, which plays an integral role in learning.

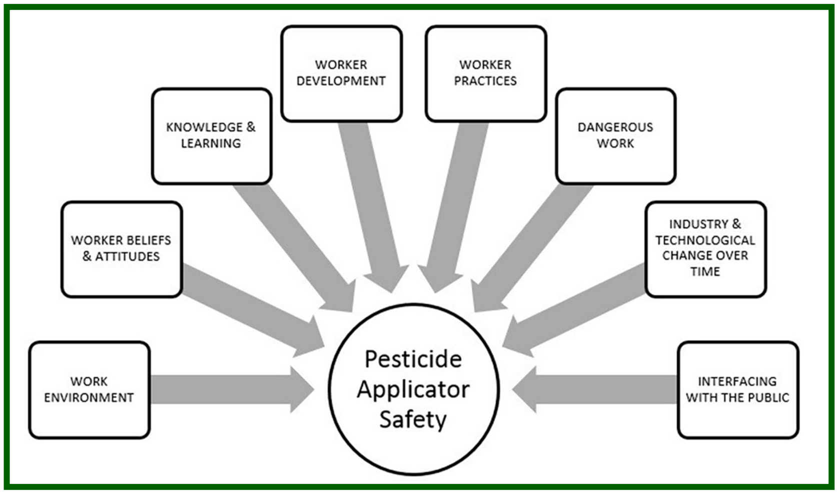

**Figure 1. Critical Components that Affect Pesticide Applicator Safety.**

Understanding the reasons pesticide applicators may take risks is key to developing effective safety training. The pilot study found that these reasons are embedded in the culture of the workforce, demonstrating the need to develop additional safety education programming that arises from the needs and motivations of pesticide applicators. Providing these workers access to research-based information may reduce risk, and training that utilizes narrative can serve to reinforce learning by providing a context. Of further interest is development of self-efficacy among pesticide applicators that may increase their safety and the safety of their co-workers. The subculture of pesticide handlers, many who are Hispanic and not licensed, is an area that requires further research. A conceptual model reveals forces that contextualize and contribute to the current pesticide safety education situation. These findings offer a positive direction in development of future educational curriculum for pesticide applicators.

## Eyespot, Cephalosporium Stripe, and Snow Mold Diseases of Winter Wheat

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Eyespot and Cephalosporium stripe diseases are most common in the high-rainfall regions of Washington, but also occur in the low- and intermediate-rainfall wheat-producing areas and have potential to cause loss in grain yield up to 50% for eyespot and 80% or more for Cephalosporium stripe. In contrast, snow mold diseases historically have been a problem on about 200,000 acres in the north-central wheat-producing area of Washington near the Waterville Plateau, and can cause complete yield loss when a susceptible variety is grown, and disease is severe.

Planting a resistant variety is the best control for these diseases. Our research has focused on identifying new and effective resistance genes to these three diseases and testing new varieties for resistance. Over the past 10 years, we have tested new varieties and advanced breeding lines for eyespot and Cephalosporium stripe resistance in inoculated field trials and used that information to provide variety ratings available on the WSU Extension Small Grains Team website (http://smallgrains.wsu.edu) and the Washington State Crop Improvement Seed Buyer's Guide. Several varieties are available with effective resistance or tolerance to these diseases. We recommend consulting the results of the WSU Variety Testing plots near you and selecting the most resistant variety that does well in your area.

During the past five years, two doubled-haploid populations were developed with a new source of snow mold resistance, PI 173438. These populations were field-tested for two years and identification of molecular markers and data analysis are nearing completion. The goal of this project is to identify molecular markers that will make it easier for breeding programs to combine several resistance genes and develop varieties with more effective snow mold resistance. Overall, we are very optimistic about this resistance based on field tests where it looks very good (Fig. 1).

**Figure 1. Regrowth following snow mold in spring 2018 of breeding lines derived from PI173438. The resistant parent, PI173438, and the locally adapted but susceptible parent, WA8137, are shown along with resistant progeny lines.**

Soil acidification is a widely occurring problem in the inland Pacific Northwest, especially in areas with greater precipitation. In 1985, Mahler at the University of Idaho documented the decrease in soil pH in north Idaho and eastern Washington from 1960 to 1980 and concluded that over 65% of the agricultural soils in the region had pH less than 6.0 by 1980. In 1992, we confirmed that Cephalosporium stripe increased in acidic soils and showed that it could be controlled by adding lime to raise pH > 6.0. However, 25 years later liming is still not practiced on a large scale and soil acidification has continued to the point where aluminum toxicity has become a problem in some areas. New approaches are needed to address this problem. Consequently, we have begun studies looking at the impact of biochar and paper mill fly ash application on soil pH, incidence/severity of Cephalosporium stripe, and productivity. In pot studies with two soils, two forms each of biochar and fly ash, and agricultural lime were applied alone and in combination to soils with low pH and high free aluminum, and then planted to a susceptible variety. Soil pH in one form of fly ash and the agricultural lime treatments increased significantly, while free aluminum also decreased, and differences in growth were dramatic, especially in the low pH, high aluminum soil (Fig. 2).

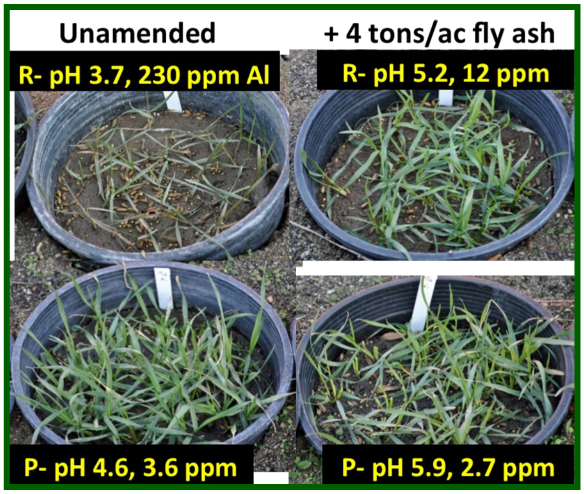

**Figure 2. Rockford (R) and Palouse (P) soils unamended and amended with 4 tons/ac lime equivalent of paper mill fly ash (FA) four months after planting. Soil pH increased significantly in both soils and free aluminum decreased in the Rockford soil, which has very high free aluminum.**

## Downy Brome Control in Winter Wheat

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Three studies were established in ‘Brundage96’ winter wheat to evaluate downy brome control with Talinor combinations plus grass herbicides and fertilizer, Osprey Xtra combined with Zidua or Axiom, and Roundup PowerMax combinations plus Outrider prior to planting near Moscow, ID. The plots were arranged in a randomized complete block design with four replications. All herbicide treatments were applied using a $CO_2$ pressurized backpack sprayer. Crop injury and downy brome control were evaluated visually during the growing season.

In the Talinor study, comparisons of Talinor were made with and without the addition of UAN in combination with grass herbicides. The Talinor label states that it cannot be combined with ammonium sulfate (AMS) due to possible increased crop injury, but many grass herbicides require the addition of a fertilizer. Talinor alone plus urea ammonium nitrate (UAN) injured winter wheat 16% at 11 DAT (days after treatment) (Table 1). By 31 DAT, PowerFlex and Osprey alone or combined with Talinor without UAN injured wheat 16 to 25%. Downy brome control was best with PowerFlex treatments (81 to 88%). Wheat grain yield was lowest with treatments without any grass herbicides and PowerFlex or Osprey alone. Grain test weight was lowest for PowerFlex and Osprey alone. Wheat grain yield and test weight was decreased with

PowerFlex and Osprey treatments due to wheat injury (chlorosis, necrosis, and vigor). The addition of Talinor safened the grass herbicide plus UAN mixtures and did not reduce wheat grain yield or test weight.

**Table 1. Downy brome control and wheat response with Talinor combined with grass herbicides and fertilizer near Moscow, ID in 2018.**

| Treatment[1] | Rate | Wheat injury | | Downy brome control | Wheat | |
|---|---|---|---|---|---|---|
| | | 11 DAT | 31 DAT | | Yield | Test weight |
| | lb ai/A | % | % | % | lb/A | lb/bu |
| Talinor + | 0.193 | | | | | |
| CoAct + | 0.058 | | | | | |
| NIS | 0.25% v/v | 0 | 0 | 0 | 1151 | 61.4 |
| Talinor + | 0.193 | | | | | |
| CoAct + | 0.058 | | | | | |
| UAN + | 15% v/v | | | | | |
| NIS | 0.25% v/v | 16 | 0 | 0 | 1462 | 61.6 |
| Talinor + | 0.193 | | | | | |
| CoAct + | 0.058 | | | | | |
| PowerFlex + | 0.0164 | | | | | |
| NIS | 0.25% v/v | 0 | 16 | 81 | 3079 | 61.6 |
| Talinor + | 0.193 | | | | | |
| CoAct + | 0.058 | | | | | |
| PowerFlex + | 0.0164 | | | | | |
| UAN + | 15% v/v | | | | | |
| NIS | 0.25% v/v | 0 | 9 | 88 | 2963 | 61.5 |
| Talinor + | 0.193 | | | | | |
| CoAct + | 0.058 | | | | | |
| Osprey + | 0.0134 | | | | | |
| NIS | 0.25% v/v | 0 | 19 | 53 | 2042 | 61.9 |
| Talinor + | 0.193 | | | | | |
| CoAct + | 0.058 | | | | | |
| Osprey + | 0.0134 | | | | | |
| UAN + | 15% v/v | | | | | |
| NIS | 0.25% v/v | 0 | 6 | 55 | 3438 | 61.6 |
| PowerFlex + | 0.0164 | | | | | |
| UAN + | 15% v/v | | | | | |
| NIS | 0.25% v/v | 0 | 24 | 82 | 1813 | 60.4 |
| Osprey + | 0.0134 | | | | | |
| UAN + | 15% v/v | | | | | |
| NIS | 0.25% v/v | 0 | 25 | 55 | 1806 | 60.6 |
| LSD (0.05) | | 1 | 11 | 26 | 1058 | 0.7 |
| Density (plants/ft$^2$) | | | | 15 | | |

[1] Sodium bicarbonate (CoAct) was used as a buffer. NIS is nonionic surfactant (R-11). UAN is urea ammonium nitrate (fertilizer). Wheat had 1 to 3 tillers and downy brome had 3 leaves to 3 tillers at the time of application on April 22, 2018.

In the Osprey Xtra study, Osprey Xtra alone or combined with Axiom or Huskie injured winter wheat 11 to 30% (Table 2). Temperatures below freezing before and after Osprey Xtra application enhanced injury. All treatments controlled downy brome 91 to 99%, except Osprey Xtra alone.

In the Roundup plus Outrider study, downy brome control was 91 and 98% with the Zidua treatments (Table 3). Roundup plus Outrider at the high rate suppressed downy brome 75%. Wheat grain yield was lowest with Roundup alone, but yield was not different from the Roundup plus Prepare treatment. Zidua treatments had lower grain test weight compared to Roundup alone (the standard). This was most likely due to higher late season moisture availability from increased downy brome control.

**Table 2. Winter wheat injury and downy brome control with Osprey Xtra combined with Zidua or Axiom near Moscow, ID in 2018.**

| Treatment[1] | Rate | Application timing[2] | Winter wheat injury[3] | Downy brome control[3] |
|---|---|---|---|---|
| | lb ai/A | | % | % |
| Zidua | 0.08 | preemergence | 0 | 95 |
| Axiom | 0.34 | preemergence | 11 | 91 |
| Zidua + | 0.08 | preemergence | | |
| Osprey Xtra | 0.0178 | 2 to 3 tiller | 11 | 99 |
| Axiom + | 0.34 | preemergence | | |
| Osprey Xtra | 0.0178 | 2 to 3 tiller | 30 | 99 |
| Zidua + | 0.08 | preemergence | | |
| Osprey Xtra + | 0.0178 | 2 to 3 tiller | | |
| Huskie | 0.217 | 2 to 3 tiller | 15 | 99 |
| Axiom + | 0.34 | preemergence | | |
| Osprey Xtra + | 0.0178 | 2 to 3 tiller | | |
| Huskie | 0.217 | 2 to 3 tiller | 20 | 99 |
| Osprey Xtra | 0.0178 | 2 to 3 tiller | 28 | 52 |
| LSD (0.05) | | | 16 | 5 |
| Density (plants/ft$^2$) | | | | 15 |

[1] All Osprey Xtra treatments were applied with a non-ionic surfactant (R-11) at 0.25% v/v and urea ammonium nitrate at 5% v/v.

[2] Application timing based on winter wheat growth stage on Oct. 10, 2017 and April 20, 2018.

[3] Evaluation date May 23, 2018.

**Table 3. Downy brome control and winter wheat response with Roundup PowerMax combined with Outrider near Moscow, ID in 2018.**

| Treatment[1] | Rate | Application timing | Downy brome control[2] | Winter wheat Yield | Winter wheat Test weight |
|---|---|---|---|---|---|
| | lb ai/A | | % | lb/A | lb/bu |
| Roundup | 1 | preplant | 0 | 991 | 58.5 |
| Roundup + | 1 | preplant | | | |
| Zidua + | 0.08 | preplant | | | |
| Outrider | 0.031 | preplant | 91 | 1713 | 56.9 |
| Roundup + | 1 | preplant | | | |
| Prepare | 0.0214 | preplant | 2 | 1560 | 59.4 |
| Roundup + | 1 | preplant | | | |
| Outrider | 0.0134 | preplant | 42 | 1850 | 58.4 |
| Roundup + | 1 | preplant | | | |
| Outrider | 0.0310 | preplant | 75 | 2105 | 57.6 |
| Roundup + | 1 | preplant | | | |
| Prepare + | 0.0214 | preplant | | | |
| Outrider | 0.0134 | preplant | 38 | 1881 | 58.6 |
| Roundup + | 1 | preplant | | | |
| Zidua + | 0.08 | postplant pre | | | |
| Outrider | 0.031 | postplant pre | 98 | 1617 | 55.9 |
| LSD (0.05) | | | 12 | 584 | 1.5 |
| Density (plants/ft$^2$) | | | 20 | | |

[1] All treatments were applied with a non-ionic surfactant (R11) at 0.25% v/v and dry ammonium sulfate at 2.5 lb/A on Oct. 9 and Oct. 11, 2017.

[2] Evaluation date July 10, 2018.

# The Effect of In-Furrow Application of Pyrethroid in Rotational Crop in Reducing Wireworm Damage in Subsequent Wheat

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The term "wireworm" is used to describe the larval stage of click beetles (Coleoptera: Elateridae). Wireworms are a major pest of many crops, including cereals and vegetables grown in the Pacific Northwest (PNW). Neonicotinoid seed-treatments are the only chemical control option registered for cereal application. The seed treatments, however, have not been effective in reducing wireworm damage in cereals. Thus, there is a need to test alternative methods, to be employed as components of an integrated management protocol. Focusing on one of the most damaging species in the PNW, the sugar beet wireworm Limonius californicus, we conducted a greenhouse study to evaluate the effect of in-furrow application of the pyrethroid bifenthrin, in a commonly planted rotation crop in the PNW, in reducing wireworm damage in the subsequent wheat crop. In the treatment where bifenthrin-treated pea was followed by thiamethoxam-treated wheat, up to 82% mortality was reported in wireworms. This mortality rate was significantly higher than those observed in treatments where untreated pea was followed by untreated wheat (30%). Germination success was relatively higher in wheat that followed pea treated with bifenthrin compared to the wheat treatments which followed untreated peas.

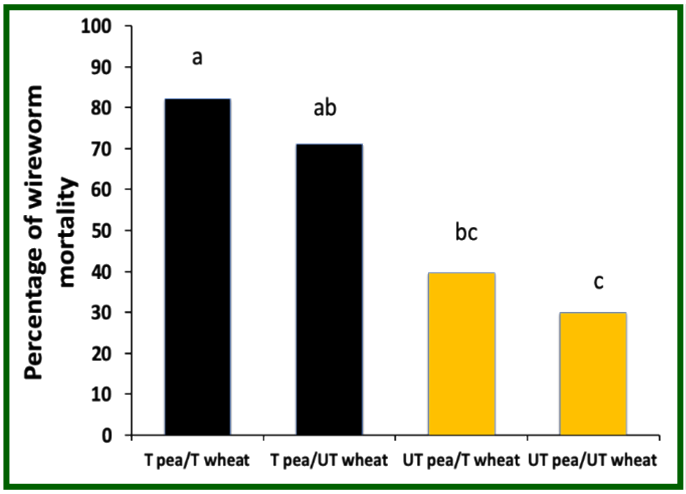

**Figure 1. Percentage of wireworm mortality. A significant difference was detected among treatments.**

**(generalized linear mixed model (GLIMMIX): F $_{3, 72}$ = 3.76, *P* = 0.0144).**

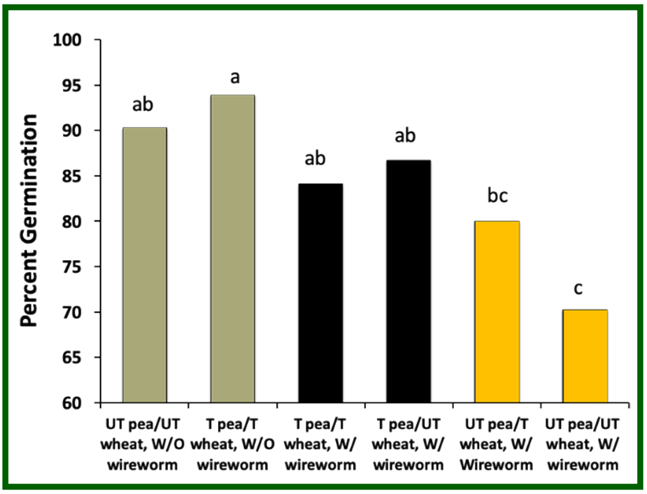

**Figure 2. Percentage of successful emergence per each treatment.**

**(GLIMMIX): F $_{5, 108}$ = 3.72, *P* = 0.0038).**

# Expression of Root Genes in a Susceptible Wheat During Infection with the Root Lesion Nematodes *Pratylenchus thornei* and *P. neglectus*

PATRICIA OKUBARA[1], AMY PEETZ[2], INGA ZASADA[2], AND RICHARD SHARPE[3]
[1]USDA-ARS, WHEAT HEALTH, GENETICS AND QUALITY; [2]USDA-ARS, HORTICULTURAL CROPS RESEARCH UNIT; [3]DEPT. OF HORTICULTURE, WSU

We recognize the utility of a collection of wheat and barley genes and regulatory sequences for expressing novel sources of genetic resistance against soilborne pathogens in these cereals. Engineered disease resistance was popular in the 1980s and 1990s, and should be given consideration again in the light of new biotechnology for producing non-GM cereal germplasm with disease resistance. Accordingly, we surveyed wheat genes that were induced in roots during infection with Pratylenchus thornei (Pt), P. neglectus (Pn), or both species combined. The aim of the research was to identify regulatory DNA segments with potential to turn on the expression of selected resistance genes when Pratylenchus is present. Our RNA sequencing survey revealed 13 expression groups representing 42 genes that were strongly induced during nematode infection. Gene functions were deduced from matches to annotated genes in the GenBank database. Many were similar to genes with known roles in host defense. Induction was often specific to one Pratylenchus species. For instance, ascorbate peroxidase and catalase peroxidase genes showed induction by Pn, whereas the glutathione S-transferases and late embryogenesis abundant proteins were induced by Pt. Genes encoding actin-11 and major pollen allergen Bet v 1 were induced by either Pt or Pn. The metacaspase gene, encoding a protein involved in plant programmed cell death, was the only one that required both species for induction. Our findings indicated that the nematode species differed in their interactions with the roots of a susceptible wheat cultivar, and that gene induction by one species generally was not affected by the presence of the other species. Further validation of gene expression will be carried out to confirm the temporal pattern of induction during infection.

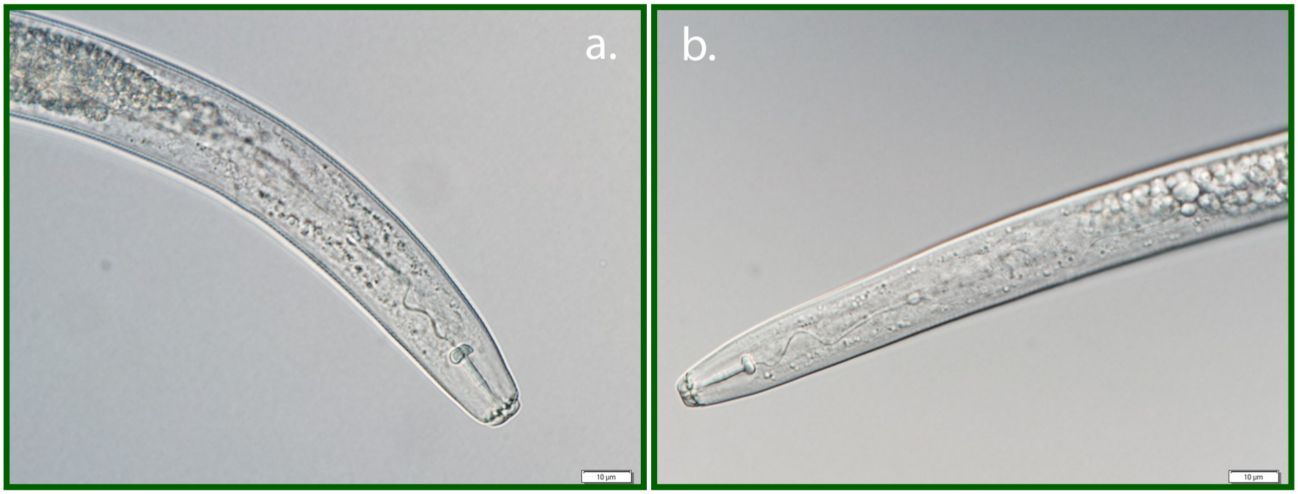

**Figure 1. Root lesion nematodes of wheat and barley. (A) *Pratylenchus neglectus* and (B) *P. thornei*. White boxes in the lower right corner indicate 10 microns.**

## Evidence of a Strong Defense Response in the Oat Pathogen *Fusarium avenaceum* F.a.1 During Aluminum Exposure and Colonization of Wild Oat Seeds

PATRICIA OKUBARA[1], RICK LEWIS[2], RUIFENG HE[3], TARAH SULLIVAN[2], DAVID GANG[3], AND E. PATRICK FUERST[2]
[1]USDA-ARS, WHEAT HEALTH, GENETICS AND QUALITY; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU; [3]INSTITUTE OF BIOLOGICAL CHEMISTRY, WSU

Buildup of seeds of wild oat (*Avena fatua*) in dryland wheat production systems can be a major yield-limiting factor in the Pacific Northwest, USA and in other parts of the world. Wild oat often competes with wheat in regions undergoing soil acidification, in which soluble concentrations of many metals, including aluminum (Al), are increased. Understanding the molecular mechanisms underlying weed seed interactions with pathogens and soil chemical factors is crucial to developing novel weed seed suppression technologies. A Pacific Northwest strain (F.a.1) of a soilborne fungal pathogen, *Fusarium avenaceum*, was shown to preferentially decay wild oat caryopses (seeds without hulls) compared with those of wheat. Using a transcriptomic approach, we observed differential expression of F.a.1 genes upon exposure to chronic, sublethal concentrations of Al (400 µM) and/or during its colonization of wild oat caryopses. Caryopsis colonization was associated with increased expression of genes involved in stress/defense, organic acid metabolism, primary metabolism, amino acid/peptide/protein metabolism, and other basic metabolic processes, whereas aluminum exposure resulted in increased expression of genes involved in polyketide synthesis, iron metabolism and transport, including siderophore transport. These genes were largely repressed during caryopsis colonization and when Al was not present. The findings suggest that chronic aluminum toxicity disrupts global iron homeostasis, which leads to the expression of siderophore- and iron-related genes, and that both caryopsis colonization and aluminum toxicity uniquely influence transcriptomic responses of *F. avenaceum*.

**Figure 1. *Fusarium avenaceum* colonizing the caryopses of wild oat on synthetic medium.**

# Part 4. Breeding, Genetic Improvement, and Variety Evaluation

## Winter Wheat Breeding and Genetics

A. CARTER, G. SHELTON, K. BALOW, A. BURKE, K. HAGEMEYER, T. SEE, AND A. KONDRATIUK
DEPT. OF CROP AND SOIL SCIENCES, WSU

The Winter Wheat Breeding and Genetics Program at Washington State University remains committed to developing high yielding, disease resistant, and high end-use quality cultivars for release to maintain sustainability of production. We are using the newest tools available to accomplish this task and are excited about the breeding lines under evaluation and their release potential. We have a strong production system of doubled haploid lines which are generating bout 3,500 lines annually. About 200 populations each year are selected with markers to aid in selection for important genes for disease resistance and end-use quality. Our genomic selection efforts are progressing and we are developing models to select breeding lines using the entire genome instead of one or two markers. We have completed a lot of research on identifying markers throughout the wheat genome with traits associated with disease resistance and abiotic stress conditions. Collaboratively with the Spring Wheat and USDA Wheat breeding programs, and groups in Biological Systems Engineering and Statistical Genomics, we are expanding our systems of high-throughput phenotyping and using it for selection within the breeding program. These technologies are now being used in the breeding program to make more efficient selections. In collaboration with the Weed Science program we are expanding our efforts to develop herbicide tolerance in winter wheat to benefit the growers

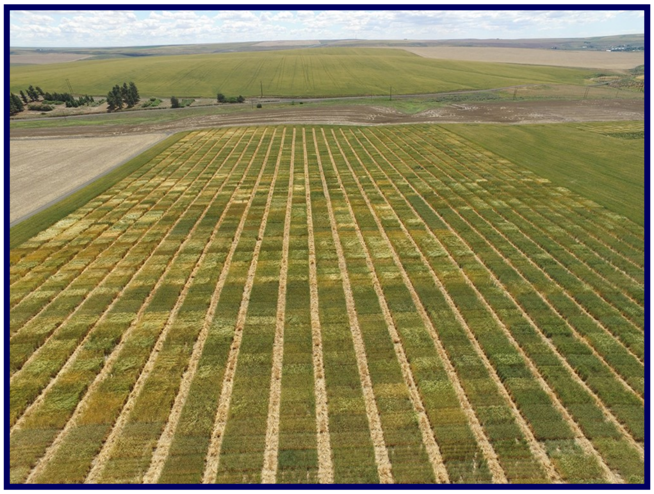

**Figure 1. Winter wheat breeding plots at Lind, Washington.**

of the state. Selection under field conditions continues for emergence from deep planting, other agronomic characteristics, diseases such as stripe rust and snow mold (and many others!), tolerance to low pH soils, and many other traits too numerous to list! The winter wheat program continues to work effectively and efficiently to develop winter wheat cultivars with high yield potential and required agronomics, disease resistance, and end-use quality parameters for the state of Washington.

Releases from the WSU winter wheat program include Otto, Puma, Jasper, and Sequoia. We also participated in the collaborative release of Curiosity CL+, Mela CL+, Resilience CL+, and Pritchett. More recently we released Purl, a high yield soft white winter wheat line for the high rainfall productions zones with high test weight, good cold tolerance, and resistance to stripe rust, eyespot foot rot, nematodes, and low pH soils. Recently recommended by the cereal variety release committee are the following cultivars:

**Figure 2. Research breeding plots being harvested.**

Stingray CL+ which is a two-gene imazamox resistant line broadly adapted to both Washington and Oregon. It has topped almost every yield trial it has been in when compared to other two-gene lines. It has good stripe rust resistance, eyespot resistance, and cold tolerance.

WA8271 is a soft white winter wheat with excellent yield potential in the less than 12-inch rainfall zones. It has high test weight, excellent tolerance to snow mold and cold temperatures, stripe rust resistance, eyespot resistance, and Fusarium crown rot resistance.

WA8268 is a hard red winter wheat targeted to the intermediate and high rainfall areas targeted to replace Keldin. It has high yield potential, stiff straw that withstands lodging, stripe rust resistance, cold tolerance, and very good end-use quality attributes.

## OSU Cereal Extension Program Updates

RYAN C. GRAEBNER AND DAISY RUDOMETKIN
COLUMBIA BASIN AGRICULTURAL CENTER, OSU

The OSU cereal extension program conducts wheat and barley variety trials in 22 locations across Oregon, and Southeast Washington, in order to evaluate the performance of new and upcoming varieties in the cereal production regions of Oregon. Wheat varieties are evaluated in four trials: the OWEYT for soft winters, the HWEYT for hard winters, the OSSYT for soft springs and the OSHYT for hard springs. Barley varieties are evaluated in the Oregon Spring Barley Variety Trial (OSBVT). We evaluate each variety in the program for yield, test weight, grain protein, plant height and heading date. We collaborate with Professor Chris Mundt, Professor Andrew Ross, and the Western Wheat Quality Laboratory to evaluate the entries for disease resistance and end-use quality. Program priorities include ensuring that our testing conditions reflect production conditions, maintaining consistency in the locations we test from year to year, and getting a head start with testing public and private experimental lines.

Trial results are available on the program's website at, https://agsci.oregonstate.edu/wheat/osu-wheat-variety-trials.

# Discovering Wheat Mutations for Herbicide Resistance

DAOLIN FU, JOAN CAMPBELL, JIANLI CHEN, AND YUEGUANG WANG
DEPT. OF PLANT SCIENCES, UI

Common wheat (Triticum aestivum L.) is a staple food crop in the world. Wheat is also the top cereal crop in Idaho, USA. Gain of herbicide resistance is one value-added trait in US farming. In wheat, herbicide resistant varieties have been successfully deployed in production, including the Clearfield Wheat Production Systems (https://agriculture.basf.com/us/en/Crop-Protection/Clearfield.html) and the CoAXium Wheat Production System (www.coaxiumwps.com).

Dr. Fu's group has developed a large mutant population, about 15,000 lines, in three Idaho-based wheat genotypes, including the winter wheat variety 'Brundage', winter wheat breeding line '01-10704A', and the spring wheat variety 'UI Platinum'. Mutagenesis was based on ethyl methanesulfonate (EMS), fast neutron, or gamma ray. The current mutant population is screened to identify herbicide-resisting wheat, which can be used to innovate cropping systems for effective weed control. To accomplish this, we are conducting four layers of research: 1) to screen insensitive mutants to herbicides with different modes of action (Table 1), 2) to identify wheat nuclear genes that are potentially targeted by herbicides, 3) to screen mutations in "target-site genes" in wheat mutant population, and 4) to test "target-site mutations" for their responses to selected herbicide groups. The generation of herbicide-resistant wheat offers a value-added trait. This research potentially benefits wheat growers as well as the wheat industry in Idaho by providing new genetic material in wheat for resistance to herbicides.

This study was supported by the Hatch grant (IDA01587) from the USDA National Institute of Food and Agriculture and by the Idaho Agricultural Experiment Station, University of Idaho.

**Table 1. Herbicides used to screen wheat mutants in 2018-2019.**

| Herbicides | Application timing | Dose rate | Active ingredients | Location |
|---|---|---|---|---|
| Axiom | Pre-emergence | 24 oz/acre | Flufenacet/metribuzin | Field |
| Anthem Flex | Pre-emergence | 15 oz/acre | Pyroxasulfone/carfentrazone | Field |
| Valor | Pre-emergence | 10 oz/acre | Flumioxazin | Field |
| Dual Magnum | Pre-emergence | 5 pints/acre | s-metolachlor | Field |
| Outlook | Pre-emergence | 64 fl oz/acre | Dimethenamid-P | Field |
| Metribuzin | Pre-emergence | 30 oz/acre | Metribuzin | Field |
| Dual Magnum | Pre-emergence | Various doses | s-metolachlor | GH |
| Zidua | Pre-emergence | Various doses | Pyroxasulfone | GH |
| Liberty | 2 to 3 leaf | Various doses | Glufosinate-ammonium | GH |

**Note:** GH = greenhouse.

# A Gravimetric Method to Monitor Plant Transpiration Under Water Stress Conditions

LIAM DIXON, BRIAN BELLINGER, AND ARRON CARTER
DEPT. OF CROP AND SOIL SCIENCES, WSU

The water-limited potential yield of wheat (*Triticum aestivum* L.) may be largely dependent on plant transpiration behavior. Research into plant transpiration dynamics is limited, however, due to the difficulty of monitoring water use over an extended period of time. The advent of fully automated gravimetric platforms makes this research possible. These systems collect data on the weight of each pot at regular intervals and automatically dispense water once the pot weight falls below a predesignated threshold value (Fig. 1). Methods for using this equipment to study transpiration of wheat in water deficit environments are not well established. The objective of this greenhouse study was to develop a methodology to evaluate plant transpiration under terminal water stress using a gravimetric platform. In combination with the plant-pot system designed to limit non-plant water loss, the methodology proved capable of monitoring plant transpiration over a 42-day period with sufficient precision to detect significant differences between well-watered and water-stressed treatments (Fig. 2). This work lays the foundation for further research into plant water use and the identification of genotypes capable of high transpiration despite exposure to water deficit conditions. These genotypes and the traits they possess may be exploited to improve the water-limited potential yield in certain environments.

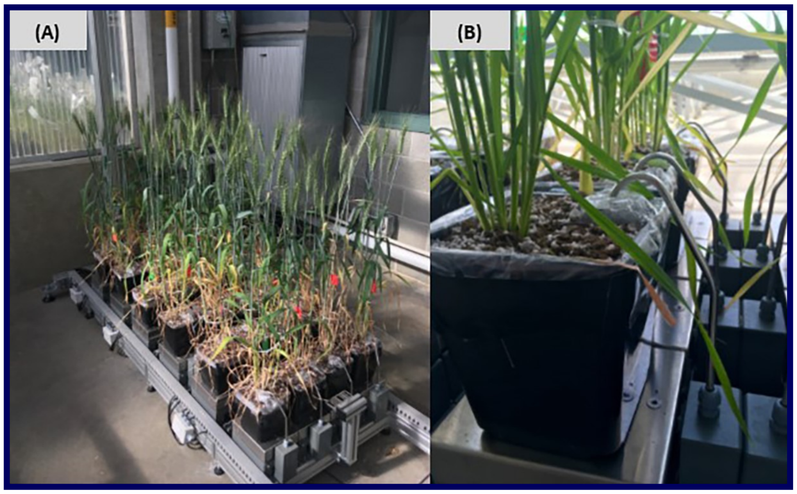

**Figure 1. View of the gravimetric platform (A) and an individual plant situated on a scale with the watering spigot ready to automatically dispense water (B).**

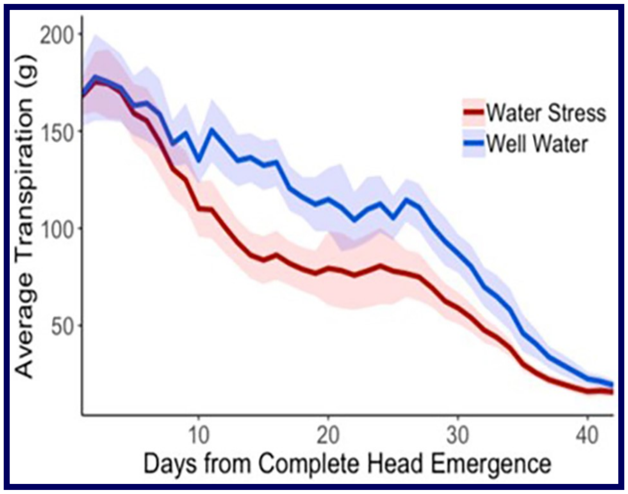

**Figure 2. Average daily transpiration for well watered and water stressed treatments.**

## Defining Conditions that Induce LMA, a Cause of Low Falling Numbers?

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[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS, WHEAT HEALTH, GENETICS AND QUALITY UNIT

**Problem:** Little is known about the temperature conditions that trigger late maturity alpha-amylase (LMA), a problem that can cause low falling numbers without rain and preharvest sprouting. The falling number (FN) test measures starch damage due to the presence of alpha-amylase enzyme in grain. The FN gets lower as alpha-amylase enzyme levels in the grain increase. Because low FN is associated with poor end-use quality, grain with an FN below 300 seconds is discounted. Late Maturity alpha-amylase (LMA) is the induction of alpha-amylase by a cold shock during late grain filling around the soft dough stage. The question is what sort of temperature differences can cause a low FN problems in Washington wheat.

**Method:** Wheat plants (soft white spring WA8124) were grown in pots in a growth chamber at the starting temperature, and spikes were tagged when they reached pollen shedding. Wheat was moved into another chamber for a 7 day cold or heat treatment at 24-26 days past pollen-shedding. For every test, there was a control that remained at the starting temperature instead of being moved to the cold chamber. Day and night time temperatures were different in order to mimic the day/night temperature differences in the field.

**Results:** We learned the following. 1) The untreated controls kept at 77/64 for the entire experiment resulted in very different alpha-amylase enzyme levels ranging from 9 to 59 units in different experiments. This means that there is an aspect of this experiment we are unable to control. This also makes it difficult to compare the fold-induction between experiments. 2) A lower cold treatment temperature does not necessarily result in higher induction of LMA since the 64°F/45°F (day/night temperature) treatment resulted in 279 units while the 60/40°F treatment gave only 44 units. 3) While a cold night of 45°F was able to induce LMA alone, much stronger LMA induction was seen when both day and night temperatures were low. 4) Previous work showed LMA with heat treatment of British wheat. No heat treatments examined here were able to induce LMA in soft white spring WA8124.

**Table 1. Comparison of different cold and hot temperature treatments on LMA induction.**

| Day/Night Temperature °F | | | $\alpha$-Amylase units per gram[1] | | Fold Induction | 1-way ANOVA | |
|---|---|---|---|---|---|---|---|
| Starting temp. | Cold or hot Treatment | Change in temp. | Untreated (U) | Treated (T) | T/U | p-value | LMA or no? |
| 77/64 | 64/45 | -13/-19 | 59±7 | 279±23 | 4.8X | <0.00001 | LMA |
| 77/64 | 60/40 | -17/-24 | 9±1 | 44±6 | 4.9X | 0.0033 | LMA |
| 77/64 | 50/50 | -27/-14 | 24±6 | 269±35 | 11.2X | 0.0048 | LMA |
| 77/64 | 77/45 | 0/-19 | 30±3 | 52±7 | 1.8X | 0.0553 | LMA |
| 77/64 | 64/64 | -13/0 | 22±3 | 28±5 | 1.3X | 0.423 | No LMA |
| 77/64 | 90/77 | +13/+13 | 13±2 | 12±1 | 1.0X | 0.967 | No LMA |
| 68/50 | 86/68 | +18/+18 | 67±9 | 69±19 | 1.0X | 0.837 | No LMA |
| 86/50 | 68/50 | -18/0 | 16±1 | 13±2 | 0.8X | 0.809 | No LMA |

[1] Note: a standard of FN 300 sec gave 18 and of FN 244 gave 56 alpha-amylase units per gram. So a value over 18 units could result in an FN below 300 second.

## The USDA-ARS Western Wheat Quality Laboratory

CRAIG F. MORRIS AND DOUGLAS A. ENGLE
USDA-ARS WESTERN WHEAT QUALITY LABORATORY

The mission of the USDA-ARS Western Wheat Quality Lab is two-fold: conduct milling, baking, and end-use quality evaluations on wheat breeding lines, and conduct research on wheat grain quality and utilization. Our web site: http://wwql.wsu.edu/ provides great access to our research and publications.

Our current research projects include soft durum wheat, grain hardness, arabinoxylans, puroindolines, polyphenol oxidase (PPO), waxy wheat, and quinoa. Our recent publications include the development of haplotype-specific molecular markers for the low-molecular-weight glutenin subunits, published in Molecular Breeding. The evaluation of ELISA test kits for wheat, published in Cereal Chemistry. A historical review of wheat breeding for quality was published in Cereal Chemistry. The relationships between falling number, $\alpha$-Amylase activity, milling, cookie, and sponge cake quality of soft white wheat were studied and published in Cereal Chemistry. A study on the determinants of wheat noodle color was published in the Journal of the Science of Food and Agriculture. Color characteristics of white salted, alkaline, and egg noodles prepared from *Triticum aestivum* L. and a soft kernel durum *T. turgidum* ssp. *durum* was published in Cereal Chemistry. The influence of soft kernel texture on fresh durum pasta was published in the Journal of Food Science. Research on microwave fixation enhances gluten fibril formation in wheat endosperm was published in Cereal Chemistry and The Western Wheat Quality Lab—Seventy Years of Service was published in the December issue of Wheat Life magazine. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Glee and Dayn.

## USDA-ARS Club Wheat Breeding: Are You in the Club?

KIM GARLAND-CAMPBELL[1], PATRICIA DEMACON[2], EMILY KLARQUIST[2], NUAN WEN[2], AND BRIAN BELLINGER[1]
[1]USDA-ARS; [2]WASHINGTON STATE UNIVERSITY

The focus of the USDA program is to develop high quality club wheat and soft white cultivars, and to incorporate germplasm for disease resistance into adapted wheat germplasm. The breeding program has yield trials in 11 locations across Eastern Washington, Idaho, and Oregon that allow us to test our cultivars in a variety of different climates so we can release high-performing varieties adapted to specific PNW climates. Several of these trials are planted as collaborations with the WSU Winter Wheat and the WA Cereal Grain Variety testing programs.

The top goals for 2019-2020 are to; 1) to develop club wheat varieties with earlier maturity, better emergence and better snow mold tolerance 2) utilize the new freeze test chambers to increase cold tolerance screening nurseries in the greenhouse; 3) increase the size of our early generation populations through a process formerly known as 'mini-bulking'; 4) screen our club material in the field and greenhouse for resistance to Beyond®; 5) identify novel sources of stripe rust resistance from synthetic wheat and selected landrace lines; 6) develop knowledge about the effects of known resistance genes against local the local cereal cyst nematode (*Heterodera filipjevi* and *H. avenae*) pathotypes and identify unknown resistance genes in PNW wheat materials; 7) utilize bulked segregant analysis to clone the club wheat *compactum* (C) gene that we previously mapped on chromosome 2DL near centromere.

**Figure 1. The field crew after headrow harvest at Spillman Farm in Pullman, August 2018.**

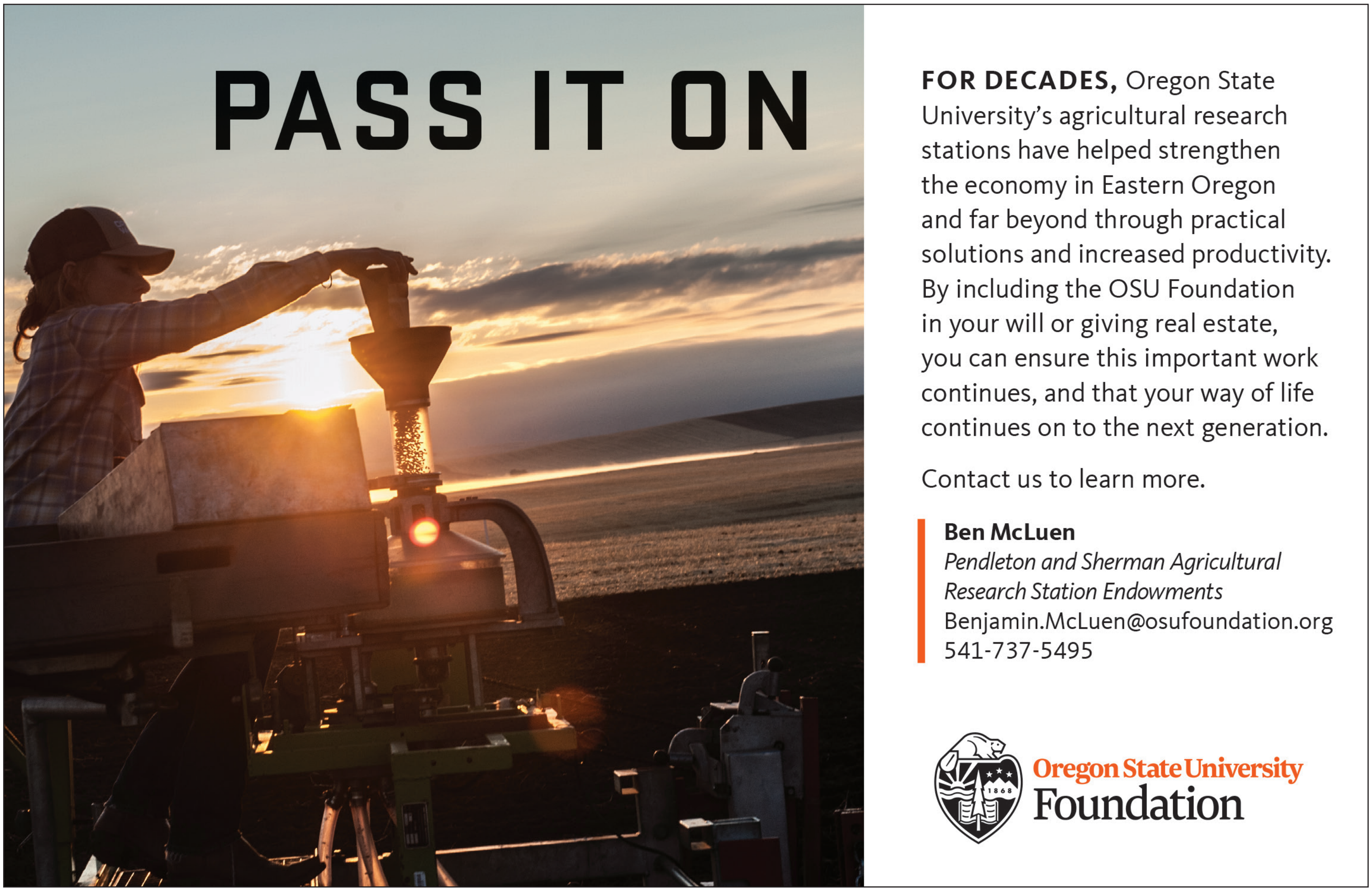
In 2018, the Plant Growth Facility at Washington State University installed two new cold tolerance chambers, giving the breeding programs the ability to triple the amount of lines screened in a given year. We will increase the number of lines in our cold tolerance nurseries, run our early generations through the chambers using the mass selection approach, and have the ability to give graduate students more access to cold tolerance testing for their research projects. A new technique from a rapid breeding method known as 'mini-bulking' could allow us to increase the size of our early generation headrows. This allows us to establish large head row nurseries and select early maturing lines in our nurseries at Pendleton, OR, at Lind, and in Douglas County to select for emergence and snow mold tolerance.

Our program is also working hard to find a two-gene IMI club for our growers. We currently have material in the field and new populations that will be tested with Beyond® in the greenhouse this coming year. We are continually screening the Western Regionals, Variety Trials, and our own breeding nurseries for resistance to stripe rust. In the coming year, you may find our seedling data coming from our new LemnaTec imaging system. Our lab hopes to use this as a high-throughput and accurate method for quantifying resistance to stripe rust and other diseases in the greenhouse.

Figure 2. Castella Club Wheat at a plot tour in 2017.

**ARS Castella (ARS20060123-31C)** is the latest variety released by the USDA-ARS. It is a tall semi-dwarf soft white winter club that has performed well all across Eastern Washington. Castella's target area is the intermediate rainfall region but it has performed very well in the dry region as well. It is resistant to stripe rust and pre-harvest sprouting, and has shown to be aluminum tolerant as well. Castella has moderate emergence, good yield potential, and excellent club wheat quality. It can lodge under high levels of nitrogen. Castella is under Foundation Seed increase in 2019.

Photo by Karen Sowers.



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